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The Practicability of Spectrographic Estimation of the Minor Components of Soils

By A. C. Oertel, M.Sc.

Summary.

It has been shown that the minor components of a soil can be estimated by spectrographic methods. In some cases, no preparatory chemical treatment of the residue from a soil extract is required; in other cases, removal of the iron by chemical means is necessary.

Several methods for estimating the minor components are available; the advantages and disadvantages of each method are discussed.

When compared with the purely chemical methods available, the spectrographic methods have the advantages of speed, simplicity, reliability, low cost, and permanency of record of the analysis.

1. Introduction.

It has been pointed out recently that those components of a soil which are present in very minute amounts, of the order of a few parts per million, may be of importance in their relation to certain stock and plant diseases. In Australia, Marston (1) and Lines (2) have shown that minute doses of cobalt appear to cure certain sheep sicknesses, and workers in New Zealand have had similar experiences (3). It has also been noticed that a deficiency of boron appears to cause such plant diseases as heart rot in swedes and turnips. In South Australia, too, it has been found that, owing to a deficiency of manganese, some soils need a top dressing of that element before cereals can be grown successfully on them. These are a few interesting cases; and it is probable that other diseases, the causes of which are at present obscure, will eventually be found to be connected with a deficiency of some necessary element.

The diseases referred to above appear to be associated with particular types of soil, and this apparent association has directed attention to the importance of developing methods of analysis for the detection and estimation of the minor components of soils. Purely chemical methods are available (4), but the processes involved in such methods require several days for their completion. The number of the separations which are necessary (iron and aluminium must be removed, and the minor components must be separated from each other and from manganese) affords many chances for the introduction of the elements as impurities

in the reagents used, for losses due to absorption by precipitates and to incomplete preciptation of the elements themselves, and for the introduction of errors due to the incomplete removal by precipitation of an element which can interfere in the estimation of a minor component.

Spectrographic methods appeared to offer many advantages; and in order that they should be investigated the writer was appointed a Research Student by the Trustees of the Science and Industry Endowment Fund. The investigations were carried out in the laboratory of the School of Natural Philosophy of the University of Melbourne, under the direction of Professor T. H. Laby.

2. Excitation of the Sample.

When dealing with substances such as the residue from a soil extract (the solution obtained by treating a soil with concentrated hydrochloric acid under standardized conditions), three methods of exciting the sample, so that it will emit characteristic radiations, are available:—

(*a*) the flame,

(*b*) the electric arc, and

(*c*) the condensed electric spark.

The spectra obtained are known as flame spectra, arc spectra, and spark spectra. Each element emits a unique flame spectrum, a unique arc spectrum, and a unique spark spectrum.

(a) Excitation by the Flame:

For the satisfactory production of a flame spectrum, a very hot source is necessary. Lundegardh found that fuel of air and acetylene gave the most suitable flame (5), while Ramage used oxy-hydrogen and oxy-coal-gas flames (6). The excitation of the sample by means of a flame has the big advantage that a very steady source of light is obtained; but the low sensitivity of the method for the heavier metals, combined with the very low concentration of the minor components of a soil extract, render such excitation useless for the detection of those components unless a great deal of preliminary chemical concentration is employed.

(b) Excitation by the Electric Arc:

The arc is struck between electrodes made of the material to be excited, or between electrodes made of pure graphite, pure carbon, or a pure metal, the sample being contained in a hollow made in the end of the lower electrode. This method gives a very intense source of light, and very short exposures (of the order of one minute) are sufficient when the spectrum is being photographed. Spectra of all the metals, and of a few non-metals, are easily excited, and the apparatus required is very simple, provided that a source of direct current is available. However, excitation of the sample by means of an electric arc has several important disadvantages, especially when one is dealing with minerals, powders, and the like. Many of these substances are non-conductors, or very poor conductors, of the electric current, and as a result the arc is very unsteady and unstable and is not suitable for quantitative work, as a steady reproducible source is essential for such work.

It was not found possible to secure a sufficiently steady arc when using electrodes of pure graphite to contain the sample prepared from a soil extract. A fairly steady arc was obtained when pure carbon rods were used for electrodes, but at times great variations occurred in the light-emitting power of the arc. The excitation of the sample by means of an electric arc was found very satisfactory for qualitative work; it was not used for quantitative work.

(c) *Excitation by the Condensed Electric Spark*:

The secondary winding of a high voltage transformer is connected to electrodes made of, or containing, the sample, and a condenser is connected across the spark gap. The spectrum of the air is also excited, but the intensity of the lines due to the air may be reduced to a negligible value by including a small inductance in the spark circuit. The most suitable values for both the capacity of the condenser and the inductance depend on the nature of the work to be done (7). The excitation of the sample by a condensed electric spark has many advantages. It may be used for solid, liquid, or gaseous samples; and all elements, under appropriate conditions, give spark spectra. The discharge is steadier and more controllable than the electric arc discharge, and as a result the reproducibility of spectra is better. The spark is, in general, more sensitive than the arc for non-metals and metalloids; and the non-conductivity, or poor conductivity, of the sample does not prevent the securing of a satisfactory spectrum. However, there are several disadvantages associated with this method. The intensity of the spark, as a source of light, is considerably less than that of the arc, and consequently longer exposures are necessary when the spectrum is being photographed. Fairly expensive accessory apparatus is required for the production of the high voltages, especially when no alternating current is available. The very high voltages (from ten to fifteen thousand volts) necessitate very good insulation of conductors at the high voltage and great care on the part of the operator. As in the case of arc spectra, the spark spectra of several common elements are very complex, and a large spectrograph is essential for reliable work with these elements, unless a considerable amount of preliminary chemical work is done on the sample.

It was found that excitation of the residue from soil extracts by means of a condensed electric spark discharge gave satisfactory results. The spark was steady, of a reasonable intensity, and the reproducibility was good. Exposures of from two to four minutes were found sufficient for recording the very faint lines due to the minor components, and spectra could be reproduced with an accuracy of about ten per cent. This figure is only approximate, and experience in routine work would probably enable a greater accuracy to be obtained.

3. Physical Condition of the Sample.

The sample prepared from a soil extract may be in a liquid or solid form. If a solid sample is desired, the residue itself is used; if a liquid sample is required, the residue of chlorides is dissolved in water. The use of an original solid sample has the advantages that the possibility of introducing impurities is almost negligible, the concentrations of the minor components are not altered, and no time is spent on the

preparation of the sample. It is difficult, however, to secure a uniform, representative sample, and to secure a homogeneous mixing of a reference substance (a substance added to the sample so that standard lines are introduced into the spectrum) with the solid sample.

When the sample is in a liquid form, complete homogeneity is secured; and a reference substance may be added and uniformly mixed with the sample. Since the amounts of the minor components of a soil are only of the order of a few parts per million, appreciable amounts may be introduced as impurities in chemicals used to change a solid sample into a liquid one. Also, the concentration of a component with reference to the final solution is, as a rule, lower than it was with reference to the original solid sample; and, in cases where the initial concentration is very low, the final concentration may be so low that the element in question cannot be detected by spectrographic methods.

It was found that the concentrations of the minor components of soil extracts are too low to permit of the use of a liquid sample, unless a considerable amount of chemical concentration is employed.

4. Method of Examination of the Spectrum.

Direct visual examination of a spectrum may be used, but such a method has serious limitations. Spectroscopic (that is, visual) methods are, as a rule, less sensitive than spectrographic methods, and they are not practicable for work on the minor components of soils for that reason. The method used in most work, and the only suitable one for this work, is the one in which the spectrum is photographed and the recorded spectrogram is examined at leisure. Small fluctuations in the emitting source, during an exposure, tend to average out; spectrograms taken with equal exposures are comparable. A very important advantage is that the record of the spectrum is permanent, and any analysis may be checked at some future time, or an analysis for some other element made, by a re-examination of the spectrogram.

The use of a photographic plate to record the spectrum is assumed throughout the remainder of this account.

5. Methods of Qualitative Analysis.

When pure elements are used as the sample, and the spectrograms are examined, it is found that the spectrum of each element is unique, no matter what region (infra-red, visible, ultra-violet, or X-ray) of the complete spectrum be examined. When a complex substance, containing many different elements, is used as the sample, the spectrum obtained from that substance contains lines due to each element present (provided, of course, that the element can be excited under the conditions used). The complete spectrum (in the region being photographed) of each element will not necessarily be recorded on the plate. It is found that, as the concentration of a selected component decreases, the number of its lines recorded decreases, until at very low concentrations only one or two lines are left. These lines are called the sensitive lines, or the ultimate lines; they, too, finally disappear as the concentration of the component is further decreased. If an element is present in a sample with a concentration high enough to be detected by spectrographic methods (the limiting concentration varies from one part in a hundred

to one part in a million, and is different for different elements), the ultimate lines of that element must be present in the spectrogram of the sample. This fact is very important in qualitative analyses by the spectrograph.

Once the spectrogram has been obtained, one of two methods of carrying out a complete qualitative analysis may be used. One method consists of measuring the wavelengths of all the lines in the spectrogram. Once the wavelength of a line is known accurately, the kind of atom which emits that line, under the conditions of excitation employed, may be found from wavelength tables. When every line in the spectrogram has been accounted for, the composition of the sample is known qualitatively, and, from the number of lines due to each element, an experienced analyst can often make fairly reliable, approximate estimations of the amount of each element present.

That method is tedious, and several hours are needed for its completion. It is, however, much more rapid, and very much less expensive, than a corresponding chemical analysis. As was noted above, if any element is present in the sample with a concentration sufficiently high for detection by spectrographic methods, the ultimate lines of that element are present in the spectrogram of the sample. By carrying out a search for the ultimate lines of all the elements likely to be present in the sample, a complete qualitative analysis may be made. This method is speedy (an allowance of one minute for each element looked for would be generous for an experienced analyst working with up-to-date equipment) and as accurate as the more tedious one, provided that care is taken not to confuse weak lines of a main component with ultimate lines of a minor component. A powder, called "raies ultimes powder" (or "R.U. powder"), is available, which gives a spectrogram containing the ultimate lines of about fifty elements. If a spectrum of this powder is photographed in juxta-position with that of the sample, the search for ultimate lines is expedited.

In the case of a routine examination, such as the examination of a soil extract residue for the presence of the minor components, the qualitative analysis may be made in a few minutes, once the spectrogram has been obtained. The analyst has merely to look at the spectrogram (under a low-powered microscope, preferably), and can say at once which of the minor components are present, as the position and grouping of the ultimate lines in question soon become well known. Experience also permits of an approximate estimate of the amounts present, from the intensity of the recorded lines.

6. Methods of Quantitative Analysis.

There are several different methods of quantitative analysis by the spectrograph, and numerous modifications of these methods to suit special routine analyses. All methods of quantitative analysis depend on a direct or indirect correlation of the intensities of lines due to the element in question with the concentration of that element in the sample.

In this account only those methods which are applicable to the estimation of the minor components of soils will be discussed.

(*a*) *Correlation of the Number of Lines with Concentration of Element*:

Since the number of lines due to any one component of a sample decreases as the concentration of the component decreases, it is obvious that the number of lines recorded could be made to give a measure of the concentration of the element emitting those lines. Such a method of analysis would be very simple and fairly rapid. However, the number of lines due to an impurity depends, as well, on the volatility of the main components of the sample, on the nature of the main components, and on the electrical conditions of the arc or spark. Degrees of concentration of the order of 0.001 per cent, 0.01 per cent, 0.1 per cent., and so on, are usually the limits of accuracy.

In the case of a sample prepared from a soil extract, the nature of the main components is fairly constant, and so is the volatility of the sample (such contrasts as lead and gold provide do not occur); and in routine analyses the electrical conditions of the arc or spark would be fixed as accurately as possible. The limits of accuracy may also be increased by noting the intensities of the lines as well as the total number, and by recording the concentrations at which each separate line first appears on the plate or disappears from the plate.

Using cobalt as the minor component, in synthetic samples, it was found that, as the concentration was increased from one to fifty parts per million (referred to the original soil), the number of lines due to cobalt, in a fixed region of the spectrogram, increased from one to twenty-four; and by noting the intensities of the lines, using an arbitrary standard, an estimate of the amount of cobalt present in the soil could be made with an accuracy of about 20 per cent. (of the actual amount present), allowance being made for variations in the electrical conditions and the light-emitting powers of the spark. Such a degree of accuracy is due partly to the fact that the cobalt spectrum is very rich in lines, and the number recorded on the plate changes rapidly with changes in the concentration of the cobalt. At the other extreme is an element like boron. The number of lines recorded in this case is only two over the whole range of concentrations used, and the method of quantitative analysis discussed above cannot be used.

(*b*) *Internal Standard Method* (7):

Pairs of lines, one of the pair from a main component and the other from the minor component, are selected, such that the lines of a pair are of equal intensity at a given concentration of the minor component expressed with reference to the selected major component. The lines selected are also such that the intensity ratio of the lines of each pair is not very much affected by variations in the electrical conditions of the arc or spark. Another pair of lines is selected, the intensity ratio of which changes rapidly with variations in the electrical conditions of the arc or spark. This pair consists of two lines from the selected major component, and the lines are of equal intensity when the correct electrical conditions obtain. The accuracy of an analysis by this method depends partly on the step from one concentration, for which an homologous pair has been recorded, to the next concentration for which a pair has been recorded. The closeness of such degrees of concentration depends on the number of homologous pairs which can be found in the total range to be investigated; and the number depends on the nature of the spectra involved.

When one is dealing with the minor components of a soil, the obvious major component to be selected to provide one line for the homologous pairs is iron, as the iron spectrum is very rich in lines of all degrees of intensity. Of the minor components, which were considered in this work (boron, copper, cobalt, lead, nickel, and zinc), both cobalt and nickel have spectra very like that of iron, as regards complexity, and the internal standard method appears to have great possibilities for the estimation of those minor components. In such a method, the amount of the minor component relative to the amount of iron, not to the amount of original soil, would be estimated.

No additional apparatus is required for this method, and the method is rapid, a visual examination of one spectrogram enabling the analysis to be made. The spectrogram automatically records whether the electrical conditions of the arc or spark have been correct or not, and fluctuations in the light-emitting power of the source have no pronounced effect, as both lines of the homologous pair are affected. The intensity ratio of the lines of an homologous pair is not affected by the presence of other substances in the sample, nor by the physical condition of the sample. However, the degrees of concentration of the minor component for which homologous pairs can be found are irregularly spaced, and the method cannot be applied satisfactorily to elements with few lines in their spectra. Also, a separate calibration is necessary for each combination of the main component with the minor components; and these calibrations require a fair amount of time.

Unfortunately, no practical tests of this method could be made, as the quartz spectrograph which was available cannot be used for the detection of cobalt and nickel, among others, when present in very small amounts with iron as the main component.

(*c*) *Ratio Quantitative System* (8):

When wishing to apply this method of analysis, the relative amounts of the major components must be known fairly accurately (this determination may be made chemically or by means of the spectrograph). Synthetic samples are prepared, containing the same amounts of the major components as the actual sample and graduated amounts of each of the minor components to be estimated. The intensities of the lines due to the main components as recorded in the spectrograms of the sample and of the standard syntheses will be the same; and by comparing the intensities of lines due to the minor components as recorded in the spectrogram of the actual sample with the intensities of the corresponding lines recorded in the spectrograms of the synthetic samples, an estimation may be made of the limits within which the concentrations of the minor components of the sample lie. Should a closer approximation to the amounts present be desired, another series of synthetic samples is prepared, containing graduated amounts of the minor components covering only the range on which the first test showed the amounts to be. The final accuracy depends mainly on the accuracy with which the conditions of excitation can be reproduced, and varies from 5 per cent. to 10 per cent. of the actual amount present.

This method of analysis is fairly rapid, for, in routine work especially, it would not be necessary to prepare synthetic samples for every analysis. The standard spectrograms, prepared for one analysis, would be filed for future reference; and in the case of purely routine work, in a

short time, reference would be made only to spectrograms already prepared, new syntheses being necessary only once in a while. Only one spectrogram of the sample is necessary for a qualitative and quantitative survey of all the minor components present, and one series of synthetic samples would contain graduated amounts of all the minor components; one does not require a separate series for each minor component. On the other hand, some chemical treatment of the sample is necessary in most cases; and a supply of exceptionally pure chemicals (as nearly spectroscopically pure as possible) is necessary for the syntheses. Chemically pure reagents must always be tested spectrographically.

A thorough examination was made of this method of quantitative analysis, and it was found satisfactory. The presence of varying amounts of other minor components did not affect the accuracy of the estimation of any one of them; and fairly large variations (of the order of 100 per cent. and greater in some cases) in the relative amounts of the major components, provided the total mass did not vary, had no appreciable effect on the accuracy of the estimation of any one of the minor components. If the mass of the residue obtained from, say, one gram of soil varies, as it does in practice, a correction must be applied. The result obtained, by comparison with the standard spectrograms, must be multiplied by the ratio of the mass of the residue from the actual sample to the mass of the residue from an equal amount of standard synthetic sample. This is because a variation in the mass of the residue alters the effective concentration of the minor components; and, of course, equal masses of the residue are used in obtaining the spectrograms, as that is essential for quantitative work.

7. Qualitative and Quantitative Analyses of a Soil for the Minor Components.

All the investigations were carried out with synthetic samples, for obvious reasons. Some work has been done with soils; and a short account of the application to an actual soil of the methods found most satisfactory will now be given.

The procedure, after the residue from the soil extract has been obtained, depends on the dispersion of the spectrograph available and also on the nature and amounts of the minor components to be estimated. As far as all the chemical work is concerned, standard practice has been followed (4), and for that reason no details are given.

Method A.—If the composition of the soil is known as far as the major components are concerned, enough of the soil to yield at least 0.01 gram of final residue for each spectrogram required is treated with the required amount of concentrated hydrochloric acid under the standardised conditions for extraction used in chemical analysis. If no information concerning the major components is available, about one (1) gram of air-dry soil is a suitable amount. In either case, the resultant solution is filtered, evaporated to dryness on a water-bath, and treated with fuming nitric acid to remove organic matter. The residue is converted into chlorides or sulphates; it does not seem to make much difference whether chlorides or sulphates are used, but the one selected must be used consistently.

A hole of fixed depth and diameter, bored in the electrode, is filled with the residue, giving the fixed constant amount required for quantitative work with sufficient accuracy. The sample is excited by arc or spark, and the spectrum photographed. The time of exposure required depends partly on the spectrograph used, and the most suitable value must be determined by each analyst. After the plate has been developed, fixed, washed, and dried (for an urgent result the wet plate may be examined), the qualitative analysis, as described in the section on "Methods of Qualitative Analysis," is made. Then the quantitative analysis is done, using the same spectrogram. For the "internal standard" method, the amount of iron present in the soil extract must be known. For the "ratio quantitative system" method of analysis, if no information about the amounts of the major components is available, a sufficiently accurate estimate of the amounts may be made by noting the weight of the residue from one gram of soil and the intensities of the lines due to the major components.

The accuracy of the results has been discussed above.

Method B.—The soil is treated as for method A, except that about five (5) grams are used if no information concerning the major components is available. In such a case a sufficiently accurate estimate of the amount of the chloride residue required to yield at least 0.01 gram of final residue may be made by noting the amount and colour of the chloride residue.

The residue of chlorides is treated for the removal of iron, and the final residue (which is converted into chlorides or sulphates) is used as the sample. Qualitative and quantitative analyses are carried out as in method A, except that the internal standard method would not be suitable (the iron has been removed).

Spectrographic tests showed that the removal of iron, by the method described by J. S. Hosking (4), causes no detectable loss of the minor components when no phosphate is present, and no appreciable loss occurred when an amount of phosphate about five times as great as that usually occurring in soils was present.

The Choice of Method.—A large spectograph, one which can be used for the detection and estimation of traces of impurities in iron, is essential before method A can be used. The concave grating spectrograph (Eagle mounting) of the School of Natural Philosophy of the University of Melbourne was available to the writer for a very short period. This instrument has a dispersion, in the region of the spectrum used, about four times as great as that of the quartz prism spectrograph used for these investigations. (A big disadvantage of a grating spectrograph is that long exposures are necessary, especially for recording the very faint lines due to minor components). Tests with this instrument showed that, of the minor components used in these investigations, copper, cobalt, and nickel can be detected easily in the presence of iron when the concentration is as low as one part per million, relative to the original soil. Lead can be detected when the concentration is as low as ten parts per million, and may be able to be detected at lower concentrations. For the detection and estimation of boron and zinc, when present in concentrations ranging up to fifty parts per million, method A cannot be used.

Method B must be used if the spectrograph available is not suitable for analysing substances of which the main component is iron. It must also be used for the detection and estimation of those components which cannot be detected and estimated by method A, the reason being insufficient sensitivity of the spectrographic method for those elements. The chemical removal of iron in such cases is to increase the concentration of the minor components in question with reference to the residue used to obtain the spectrogram.

It is obvious that all chemicals used must be tested, spectrographically, for the presence of the minor components of the soil as impurities in the chemicals.

8. Conclusions.

The investigation into the applicability of spectrographic methods to the detection and estimation of the minor components of soils has shown that the spectrograph can be used for such analyses, and the methods have the following advantages (which hold in all cases where one is concerned with the detection of traces of impurities) when compared with purely chemical methods:—

(*a*) *Speed.*—The time required for a spectrographic analysis is only a fraction of that required for the purely chemical analysis. This is especially in evidence when the substance to be analysed can be used as the sample without preliminary treatment, e.g., a piece of metal.

(*b*) *Simplicity.*—The analysis involves only the photographing and examination of the spectrum emitted by the sample when suitably excited. One spectrogram gives a complete qualitative survey of the composition of the sample as far as metallic components are concerned (a few non-metals are recorded as well); and if the spectrogram is obtained under appropriate conditions a quantitative analysis may be obtained from it.

(*c*) *Reliability.*—In a purely spectrographic analysis, the chances of introducing as impurities the elements to be estimated are almost negligible, if care is taken; and in a combined chemical and spectrographic method (necessary in some cases) they are less than for purely chemical methods because less chemical treatment is used. A chemical reagent with a purity of 99.99 per cent. is considered to be reasonably pure, yet it contains one hundred parts per million of impurities; and the amounts of the minor components in soils are only of the order of a few parts per million. Again, the removal of a component, by precipitation, which can interfere with the chemical estimation of another component, is never complete, and the amount left in solution may be quite comparable with that of the component to be estimated, thus destroying the reliability of the result. When an interfering element, in a spectrographic analysis, is removed by chemical means, all that is required is that the concentration of the element be made so low that lines due to it, which are making ultimate lines of a minor component, are too weak to be recorded, although other lines of the element may still be strong enough to be recorded.

(*d*) *Sensitivity.*—Only a very small sample is required; and any preparatory chemical treatment that may be required is much less expensive and time-consuming, as a result, than the corresponding

treatment in a chemical analysis. From one to five grams of a soil are required for a spectrographic analysis (for the minor components), while fifty grams are necessary for the corresponding chemical analysis (4).

(*e*) *Permanency of Record of Analysis.*—The analysis may be checked at any future date, or an analysis for some different element may be made, by a re-examination of the filed spectrogram. No new sample is required.

(*f*) *Low Running Costs.*—The photographic plate is one of the most expensive items, but, since twenty spectrograms may easily be recorded on one 10 inches by 4 inches plate, the cost of one plate may be spread over twenty analyses. The low running costs may alone more than counterbalance the large initial cost of the equipment, when it is remembered that, barring accidents, the useful life of a spectrograph is almost indefinite.

The disadvantage of spectrographic analysis is the large initial cost of the necessary equipment.

9. Acknowledgments.

The writer wishes to express his gratitude to Mr. E. H. S. Burhop, who was in charge of the work during Professor Laby's absence abroad, and to Professor T. H. Laby, for continued help and advice. He would also like to express his gratitude to Professor J. A. Prescott, Chief of the Division of Soils, Council for Scientific and Industrial Research, for his continued interest in the work, and for much useful help and advice, especially in connexion with the chemical problems encountered.

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The Influence of Host Plant Species in Relation to the Effectivenes of the Rhizobium of Clovers.

*By T. H. Strong, B.Agr.Sc.**

Summary.

A strain of symbiotic bacteria effective with one host plant species may not be effective with all species of the cross-inoculation group. Strains of the clover-nodule producing organism, isolated from subterranean clover, have proved effective in association with that plant, and ineffective with red and white clover, and *vice versa*. The organisms freely invade all three hosts. This variation in effectiveness, which can be attributed to specific host plant reaction, is distinct from that displayed by strains effective or partially effective upon one particular host, a variation attributed to "virulence." The results of the experiments discussed have an important bearing upon the development of the practice of seed inoculation of the clovers, both in regard to the culture to be used and to the field of application. So far, no strains have proved highly effective upon all three host plants.

1. Introduction.

Root-nodule bacteria are not always highly beneficial to the particular host plant which they invade. Intrinsic differences in strains of the specific organism exist, and the net result of the association, which is expressed finally by the growth of the plant, varies between wide limits when the plant is dependent upon the organism for its supply of nitrogen. Certain inherent characteristics of the host plant species have a profound influence upon the effectiveness of particular strains of the symbiotic bacterium. The plant may be susceptible to invasion but subsequently does not respond normally; the development of active bacterial tissue is limited, and numerous but small and ineffective nodules are produced. The influence of host plant species upon the effectiveness of the Rhizobium of clovers (*R. trifolii*) will be discussed in the light of results obtained with the species *Trifolium subterraneum*, *T. pratense*, and *T. repens*, inoculated with particular strains of the specific symbiont.

Strains of nodule bacteria which are non-beneficial are of common occurrence and have been discussed by many workers. The subject has been reviewed by Fred, Baldwin, and McCoy (1). Such strains usually produce small nodules distributed all over the root system, whilst effective strains produce large nodules or "bunches" upon the upper portion of the tap root and proximal portions of the secondary roots. The morphology of ineffective nodules has been discussed by Thornton (2). He states that their small size is apparently due to an early cessation of cell division in the nodule meristem, and that poor nitrogen fixation may be due to the small amount of active tissue formed in these nodules. In the following discussion, the terms "ineffective" and "effective" are used to describe the distinct types of nodulation illustrated in Plate 2†, Figs. 1 and 2; Plate 3, and Plate 4. Plants bearing the typical ineffective nodules are benefited little or not at all by their presence.

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† For plates see facing page 78.

2. Experimental.

A series of isolations of *Rhizobium* was made from subterranean, red, and white clovers obtained from various sources. These three host species were grown in pots under strictly controlled conditions, inoculated with the various Rhizobial strains. The yield of dry matter obtained after 11-12 weeks' growth was used to compare the effectiveness of the strains. The pots contained 4 kilos. of sterilized leached sand to which was added a basal nutrient dressing not containing nitrogen. Eight plants per pot were grown, and the necessary precautions made to avoid contamination by Rhizobia in wind-borne dust. Controls were successfully maintained free from infection. The sand of the pots was held at 50-70 per cent. of the total moisture-holding capacity. Four replications were employed, and the pots were so arranged as to permit an analysis of variance to be made. A statistical comparison of mean dry weight yields per pot is included in the table of results.

A considerable range in the effectiveness of the strains isolated from subterranean clover is indicated. The outstanding feature is the failure of the strains isolated from red and white clover to benefit subterranean clover. The typical ineffective nodulation produced in each case is illustrated in Plate 2, Fig. 1.

Strains isolated from red and white clover have thus proved effective upon both species. The range of effectiveness varies somewhat according to host, but strains have proved highly effective upon both species. The outstanding feature is the comparative failure of strains isolated from subterranean clover, to benefit either red or white clover. The strain RT. 8 appears to have given a slightly increased yield over the control. The typical ineffective nodulation produced by the subterranean clover strains upon red and white clover is illustrated in Plate 3, Fig. 2.

Both Tables 1 and 2 show that, in general, the effectiveness of the Rhizobial strains as measured by the yield of the host plant is reflected in the proportion of nitrogen in the plant, high effectiveness being associated with the higher nitrogen levels.

TABLE 1.—EFFECTIVENESS OF RHIZOBIAL STRAINS UPON SUBTERRANEAN CLOVER.

Strain.	Origin.	Mean Dry Wt. Yield per Pot in Grains.	Order of Yield.	Statistical Comparison.	Nitrogen in Dry Matter.
					%
RT. 9 ..	Ex subterranean clover ..	4·96	1	S. > 3–15	3·22
RT. 13 ..	Ex subterranean clover ..	4·72	2	S. > 4–15	3·26
RT. 8 ..	Ex subterranean clover ..	4·40	3	S. > 5–15	3·15
RT. 2 ..	Ex subterranean clover ..	4·15	4	S. > 5–15	3·29
RT. 3 ..	Culture from Wisconsin ..	3·19	5	S. > 9–15	3·06
RT. 6 ..	Ex subterranean clover ..	3·10	6	S. > 9–15	3·36
RT. 5 ..	Ex subterranean clover ..	2·93	7	S. > 9–15	3·35
RT. 4 ..	Culture from Wisconsin ..	2·88	8	S. > 9–15	2·99
RT. 12 ..	Culture from Department of Agriculture, Western Australia	1·81	9	S. > 10–15	2·48
RT. 1 ..	Ex red clover	·59	10	..	1·33
RT. 16 ..	Ex white clover	·54	11	..	
RT. 11 ..	Ex white clover	·53	12	..	
RT. 7 ..	Ex red clover	·51	13	..	
RT. 14 ..	Ex white clover	·51	14	..	
Control ..	.. ..	·41	15	..	

S.E. of mean of 4 replications = .180. S.> = significantly greater than.

TABLE 2.—EFFECTIVENESS OF RHIZOBIAL STRAINS UPON RED AND WHITE CLOVER.

Strain.	Origin.	Red Clover.			White Clover.			Nitrogen in Dry Matter. (Percentage).	
		Mean Dry Wt. Yield per Pot in Grams.	Order of Yield.	Statistical Comparison.	Mean Dry Wt. Yield per Pot in Grams.	Order of Yield.	Statistical Comparison.	White.	Red.
RP. 14 ..	Ex white clover	3·62	1	S. > 2–11	1·77	1	S. >-6–11	3·18	3·09
RT. 4 ..	Culture from Wisconsin	2·25	2	S. > 3–11	1·11	6	S. > 7–11	3·26	3·28
RT. 1 ..	Ex red clover	1·81	3	S. > 5–11	1·80	1	S. > 6–11	3·26	2·84
RT. 12 ..	Culture from Department of Agriculture, Western Australia	1·68	4	S. > 7–11	1·53	3	S. > 6–11	2·83	3·06
RT. 7 ..	Ex red clover	1·63	4	S. > 7–11	1·47	4	S. > 6–11	3·20	2·81
RT. 16 ..	Ex white clover	1·40	6	S. > 7–11	1·41	5	S. > 7–11	3·30	2·45
RT. 8 ..	Ex subterranean clover	0·22	7	..	0·51	7	..		
RT. 13 ..	Ex subterranean clover	0·15	8	..	0·35	8	..	2·00	1·27
RT. 6 ..	Ex subterranean clover	0·24	9	..	0·39	9	..		
RT. 2 ..	Ex subterranean clover	0·31	10	..	0·38	10	..		
Control ..	.. ..	0·16	11	..	0·15	11	..	..	..

S.E. of mean of 4 replications = ·104.
S. > = significantly greater than.

TABLE 3.—THE INFLUENCE OF HOST PLANT SPECIES UPON THE EFFECTIVENESS OF RHIZOBIAL STRAINS.

Strain.	Origin.	Comparative Effectiveness based upon Percentage of Highest Yield Obtained.		
		Subterranean Clover.	White Clover.	Red Clover.
RT. 13 ..	Ex subterranean clover	100 H.E.	20 I.E.	5 I.E.
RT. 8 ..	Ex subterranean clover	90 H.E.	25 I.E.	5 I.E.
RT. 2 ..	Ex subterranean clover	90 H.E.	20 I.E.	5 I.E.
RT. 6 ..	Ex subterranean clover ..	65 E.	20 I.E.	5 I.E.
RT. 12 ..	Culture from Department of Agriculture, Western Australia	35 P.E.	85 E.	45 E.
RT. 1 ..	Ex red clover	10 I.E.	100 E.	50 E.
RT. 16 ..	Ex white clover	10 I.E.	80 E.	40 E.
RT. 7 ..	Ex red clover	10 I.E.	80 E.	45 E.
RT. 14 ..	Ex white clover	10 I.E.	100 E.	100 H.E.
Control ..	.. ..	10	10	5

H.E. = Highly effective; E. = Effective; P.E. = Partially effective; I.E. = Ineffective.

The comparison of effectiveness with red and white clovers on the basis of these figures is not satisfactory, for the strain RT. 14 is much more highly effective in association with red clover than any of these strains appear to be in association with white clover. The table will serve to illustrate, however, that strains isolated from subterranean clover, and which are highly effective in association with that host, are ineffective with red and white clover, and *vice versa.* None of the strains tested is effective upon all three species.

3. Discussion.

It is obvious that variations in effectiveness of strains cannot always be attributed to such factors as "virulence," since a strain highly effective in association with one species may be totally ineffective with another, though that species is susceptible to invasion by the particular organism. Strains may vary in their ability to infect the host plant, and this may account at least for some of the normal variation in effectiveness of closely related strains. Failure to benefit the plant subsequent to invasion appears to be due not to an intrinsic inability of the strain to fix nitrogen and render it available, but to the lack of development of bacterial tissue. The host appears to be able to respond or react specifically to the particular organism, and cell division in the nodule meristem ceases early. Nodules remain small and, in the absence of active bacterial tissue, the plant receives no nitrogen. On the other hand, particular strains may have the power to stimulate the host plant to rapid cell division or to overcome a specific reaction or internal "resistance."

Plants receiving no nitrogen appear to remain susceptible to further invasion, and continuous infection of the developing root system occurs. Invasion by highly effective strains is followed by a well-defined resistance to further infection. Thornton (2) has suggested that resistance to root hair infection is developed as the ratio of available carbohydrates to nitrogen within the plant is narrowed, and this takes place

with the free development of active bacterial tissue which follows the invasion by effective strains. From the accompanying figures (Plate 2, Figs. 1 and 2) may be observed the relative scarcity of nodules upon the lower and distal portions of the root system invaded by an effective strain in contrast with the numerous nodules developed upon those portions of the root system invaded by an ineffective strain.

4. Agricultural Significance.

The variation in effectiveness of *Rhizobium trifolii* with host plant species has received comparatively little attention from previous workers, though Löhnis (3) has recorded a strain which was effective to *Trifolium incarnatum* and ineffective to *T. repens*, *T. pratense*, and *T. hybridum*. Subterranean clover possesses physiological characteristics distinct from the other members of the genus which are of more agricultural importance in other parts of the world where root-nodule bacteria are being investigated. In the present state of our knowledge, the same strain of nodule organism that is used for inoculating red and white clover should not be used for this species. Nor should it be assumed that effective natural inoculation of subterranean clover will follow in fields where other members of the cross inoculation group have previously grown. Other aspects of the problem that call for further investigation are the influence of repeated passage through the new host, of strains isolated from another host species. The competition of strains, too, which has attracted the attention of Thornton and his co-workers, is a subject which may prove of interest in regard to subterranean clover, for, in a preliminary experiment, highly significant depression in yield has been obtained by introducing a red clover strain to subterranean clover growing in the presence of an effective Rhizobial strain. The success of the practice of seed inoculation in areas where difficulty in the establishment of subterranean clover is experienced, can only follow the selection and use of suitable strains, and these may require to be able to offset the competition of ineffective strains in certain fields.

5. Literature Cited.

1. Fred, Baldwin, and McCoy. Root Nodule Bacteria. Madison, Wisc., 1932.
2. Thornton, H. G. *Science Progress.* 21: 247, 1936.
3. Löhnis, M. P., *Zentr. f. Bakt. Abt.* 11: 80, 342, 1930.

A Study of Productivity in Certain Introduced Pasture Grasses.

*By A. McTaggart, Ph.D.**

1. Introduction.

In a previous publication (C.S.I.R. Pamphlet No. 59), the results obtained from the study of persistency in 21 recently introduced grasses, subjected to differential treatment, were presented in tabular form. This paper, in turn, presents in a similar manner data relating to the annual productivity associated with 19 of these grasses and to their seasonal yields of air-dried forage, which data were obtained following the completion of the studies of persistency. The contiguous hundredth-acre plots carrying the various grasses, grown at Duntroon, F.C.T., on gently rolling land of silty clay loam type, were subjected to a continuation of the following treatments:

(A) One-third of each plot was mown closely every six (6) weeks (to simulate frequent grazing).

(B) One-third of each plot was mown closely every eight (8) weeks (to simulate moderately-frequent grazing).

(C) One-third of each plot was pastured closely with sheep when the growth warranted.

2. Description of Conditions and Studies.

Mowing operations were carried out almost exclusively by the use of a motor lawn mower. Just prior to each mowing or each pasturing-off, a system of random sampling of the herbage, calculated to yield data which on the average would give an indication of the annual and seasonal productivity associated with the various swards, was adopted. The precise method used was to throw at random a wooden frame, one metre square, on to each sub-plot. After pressing down with the foot the corners of the frame, the herbage was shorn off with a large sheep-shearing machine (hand driven). A stubble of approximately half an inch was left, and the shorn herbage from each square was carefully gathered and placed in a sugar bag for drying later in the open and under a roof beneath which the air freely circulated. The average weight of air-dried forage from duplicate cuttings represented the yield of such material per square metre.

Table 1 sets out the data obtained by this means under all conditions of environment and treatment. It furnishes the total annual weights of air-dried forage calculated to tons per acre. Data showing the average seasonal productivity in grams per square metre, for the various treatments, over all plots, are also included in the table. The relative yields of air-dried grass per annum associated with all plots are also shown, such yields being calculated on the basis of, or in relation to, 100—the yield assigned to C.P.I. 1305 *Phalaris stenoptera*, which under two out of three treatments gave the lowest actual yield.

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TABLE 1.

Weight (in grams) per square metre of air-dried grass.

Date of Cutting Quadrats.	*Agropyron cristatum* (C.P.I. 1089).	*Agropyron cristatum* (C.P.I. 1296).	*Agropyron intermedium* (C.P.I. 1358).	*Agropyron intermedium* (C.P.I. 1342).	*Brachypodium phoenicoides* (C.P.I. 1719A).	*Brachypodium phoenicoides* (C.P.I. 1719B).	*Bromus inermis* (C.P.I. 1297).	*Bromus inermis* (C.P.I. 1967).	*Bromus arduennensis* (C.P.I. 2382).	*Bromus polyanthus* (C.P.I. 2360).	*Festuca arenaria* (C.P.I. 1294).	*Festuca rubra* var. *fallax* (C.P.I. 1293).	*Festuca rubra* var. *genuina* (C.P.I. 1295).	*Festuca elatior* (C.P.I. 1144).	*Festuca Mairei* (C.P.I. 1499).	*Dactylis glomerata* (C.P.I. 2145).	*Oryzopsis miliacea* (C.P.I. 1931).	*Phalaris coerulescens* (C.P.I. 1306).	*Phalaris stenoptera* (C.P.I. 1305).	*Phalaris stenoptera* (C.P.I. 1350).
Treatment (A).																				
25th April, 1935	6·5	20·0	5·0	20·1	45·0	55·0	30·0	15·0	42·5	27·5	22·5	45·0	25·0	12·5	25·0	30·0	2·5	2·0	2·5	7·5
6th June, 1935	35·0	15·0	15·0	45·0	40·0	25·0	45·0	20·0	90·0	75·0	25·0	40·0	30·0	20·0	90·0	55·0	5·0	25·0	25·0	25·0
18th July, 1935	5·0	1·0	5·0	10·0	15·0	20·0	9·0	0	17·5	15·0	8·0	5·0	11·0	15·0	20·0	20·0	1·5	7·5	3·0	2·5
29th August, 1935	0	0	0	15·0	10·0	20·0	5·0	12·0	19·0	11·0	3·0	5·0	5·0	15·0	22·0	3·0	0	4·0	5·0	8·0
10th October, 1935	6·0	2·0	2·0	12·0	1·0	17·0	5·0	3·0	20·0	9·0	13·0	2·0	2·0	10·0	20·0	15·0	0	5·0	4·0	5·0
22nd November, 1935 ..	35·0	28·0	56·0	92·0	32·0	108·0	68·7	47·0	27·5	110·5	24·0	27·5	30·0	90·5	65·5	38·5	21·0	39·5	30·0	35·0
3rd January, 1936	26·0	31·0	28·5	65·0	37·5	63·5	73·5	34·0	76·0	88·5	30·0	12·5	18·5	38·5	46·0	13·0	18·5	15·0	21·0	20·0
14th February, 1936 ..	34·5	60·0	40·0	90·5	55·0	117·5	121·5	65·0	98·0	176·0	37·0	24·5	38·0	43·5	62·5	59·0	49·5	29·5	24·5	28·0
27th March, 1936	23·5	14·5	22·5	37·0	20·0	70·5	47·0	16·0	77·5	89·0	37·5	8·5	19·0	35·0	56·0	50·0	35·0	21·5	16·5	28·5
8th May, 1936	12·5	3·5	5·5	20·0	2·0	15·0	10·0	3·0	13·0	25·5	4·0	3·5	7·5	11·0	24·0	12·5	7·0	8·5	3·0	3·5
Totals	184·0	175·0	179·5	406·5	257·5	511·5	414·7	215·0	481·0	627·0	204·0	173·5	186·0	291·0	431·0	296·0	140·0	157·5	134·5	163·0
Tons per acre per annum ..	0·732	0·696	0·714	0·822	1·025	2·036	1·650	0·856	1·914	2·495	0·812	0·690	0·740	1·158	1·715	1·178	0·557	0·627	0·535	0·649
					Av. 1·530															
Relative yield (on basis of 100 for annual yield of C.P.I. 1305 —*Phalaris stenoptera*)	136·80	130·11	133·45	153·53	191·44	380·25	308·32	159·85	357·62	466·16	151·67	128·99	138·28	216·35	320·44	220·07	104·08	117·10	100·00	121·18
					Av. 285·84															
Treatment (B).																				
12th April, 1935	15·0	24·0	10·0	24·0	62·5	25·0	17·5	20·0	60·0	55·0	30·0	30·0	40·0	52·5	14·0	30·0	20·0	7·5	7·5	5·0
6th June, 1935	20·0	40·0	25·0	35·0	55·0	50·0	35·0	40·0	65·0	75·0	25·0	45·0	30·0	85·0	55·0	70·0	15·0	30·0	20·0	30·0
4th August, 1935	10·0	5·0	8·0	10·0	18·0	20·0	15·0	20·0	15·0	35·0	15·0	10·0	10·0	25·0	22·0	23·0	15·0	25·0	5·0	20·0
30th September, 1935 ..	2·0	10·0	3·0	15·0	15·0	20·0	14·0	15·0	5·0	55·0	15·0	20·0	15·0	55·0	20·0	10·0	3·0	15·0	5·0	13·0
22nd November, 1935 ..	32·5	27·5	57·5	73·5	26·5	53·5	58·5	40·0	29·0	97·5	37·5	27·0	32·0	148·5	26·0	32·0	48·5	41·2	26·5	29·0
20th January, 1936 ..	14·5	20·0	48·0	61·5	50·5	55·0	54·5	27·5	58·5	86·0	16·0	6·5	15·0	59·0	18·0	10·5	40·5	30·0	12·5	8·0
13th March, 1936	42·0	55·5	52·5	67·0	32·0	16·0	66·5	31·5	80·0	121·0	48·0	13·5	16·5	130·0	31·5	37·0	78·5	51·5	25·5	29·0
8th May, 1936	31·0	16·5	15·0	49·5	15·5	53·5	30·0	5·5	18·0	41·5	7·0	5·0	5·5	51·5	8·5	16·0	18·5	11·5	12·5	14·0
Totals	167·0	198·5	219·0	335·5	275·0	293·0	291·0	199·5	330·5	566·0	193·5	157·0	164·0	606·5	195·0	228·5	239·0	211·7	114·5	148·0
Tons per acre per annum ..	0·665	0·790	0·871	1·335	1·094	1·166	0·871	0·794	1·315	2·253	0·770	0·625	0·653	2·414	0·776	0·909	0·951	0·842	0·456	0·589
					Av. 1·130															
Relative yield (on basis of 100 for annual yield of C.P.I. 1305 —*Phalaris stenoptera*)	145·85	173·36	191·26	293·01	240·17	255·89	191·26	174·23	288·64	494·32	168·99	137·11	143·23	529·69	170·30	199·56	208·73	184·89	100·00	129·25
					Av. 248·03															

TABLE 1—*continued.*

Weight in grams per square metre of air-dried grass.

Date of Cutting Quadrats.	*Agropyron cristatum* (C.P.I. 1089).	*Agropyron cristatum* (C.P.I. 1296).	*Agropyron intermedium* (C.P.I. 1358).	*Agropyron intermedium* (C.P.I. 1342).	*Brachypodium phoenicoides* (C.P.I. 1719A).	*Brachypodium phoenicoides* (C.P.I. 1719B).	*Bromus inermis* (C.P.I. 1297).	*Bromus inermis* (C.P.I. 1967).	*Bromus arduennensis* (C.P.I. 2382).	*Bromus polyanthus* (C.P.I. 2360).
Treatment (C).										
21st May, 1935	45·0	70·0	30·0	40·0	70·0	210·0	30·0	25·0	70·0	50·0
24th October, 1935	120·0	80·0	35·0	110·0	30·0	135·0	70·0	40·0	45·0	40·0
3rd January, 1936	57·0	23·5	45·0	58·0	72·5	77·0	76·0	26·5	38·5	51·5
18th February, 1936 ..	37·0	36·5	23·5	35·5	71·5	69·5	130·0	48·5	75·0	85·5
1st May, 1936	71·5	58·0	85·5	41·5	81·5	128·5	40·5	31·5	108·0	56·5
Totals	330·0	268·0	219·0	285·0	325·5	620·0	346·5	171·5	336·5	283·5
Tons per acre per annum ..	1·314	1·067	0·871	1·134	1·295	2·468	1·379	0·682	1·339	1·128
					Av. 1·881					
Relative yield (on basis of 100 for annual yield of C.P.I. 1305 - *Phalaris stenoptera*)	187·17	151·84	124·07	161·47	184·41	351·27	196·31	97·16	109·65	160·62
					Av. 267·84					

Date of Cutting Quadrats.	*Festuca arenaria* (C.P.I. 1294).	*Festuca rubra* var. *fallax* (C.P.I. 1293).	*Festuca rubra* var. *genuina* (C.P.I. 1295).	*Festuca elatior* (C.P.I. 1144).	*Festuca Mairei* (C.P.I. 1499).	*Dactylis glomerata* (C.P.I. 2145).	*Oryzopsis miliacea* (C.P.I. 1931).	*Phalaris coerulescens* (C.P.I. 1306).	*Phalaris stenoptera* (C.P.I. 1305).	*Phalaris stenoptera* (C.P.I. 1350).
Treatment (C).										
21st May, 1935	55·0	10·0	50·0	55·0	40·0	50·0	40·0	55·0	60·0	45·0
24th October, 1935	7·0	15·0	25·0	35·0	20·0	20·0	15·0	20·0	30·0	10·0
3rd January, 1936	30·5	13·0	7·5	13·0	8·5	32·5	45·0	18·5	32·5	18·0
18th February, 1936 ..	32·5	6·0	4·0	70·5	27·0	52·0	92·5	15·5	25·0	14·0
1st May, 1936	27·0	5·5	20·5	38·0	20·0	41·5	38·0	14·0	29·0	12·0
Totals	152·0	49·5	107·0	211·5	115·5	196·0	230·5	123·0	176·5	99·0
Tons per acre per annum ..	0·605	0·197	0·426	0·842	0·460	0·780	0·917	0·489	0·702	0·394
Relative yield (on basis of 100 for annual yield of C.P.I. 1305 - *Phalaris stenoptera*)	86·11	28·04	60·62	119·83	65·43	111·04	130·59	69·68	100·00	56·09

Table 2 arranges the various grasses according to their productivity, in tons per acre per annum of air-dried forage, under treatments (A), (B), and (C).

Table 3 presents an average estimate with respect to the palatability of the various grasses in the test, this being based on periodic close observations as to the preference or otherwise for such on the part of sheep.

Table 4 gives the rainfall at Duntroon, Canberra, F.C.T., at six-weekly intervals over the period during which the data, shown in Table 1, were accumulated, viz., 12th April, 1935, to 25th April, 1936.

Table 5 classifies the various grasses in the test according to the season or seasons during which their growth appears to be more prominent.

The accompanying histograms (Figs. 1–3) show graphically the arrangement according to yield of the various grasses, under treatments (A), (B), and (C).

TABLE 2.—GRASSES ARRANGED ACCORDING TO THEIR PRODUCTIVITY (TONS PER ACRE PER ANNUM OF AIR-DRIED FORAGE) UNDER TREATMENTS (A), (B), AND (C).

Treatment (*A*).	*Treatment* (*B*).	*Treatment* (*C*).
1. *Bromus polyanthus* (2360*)	1. *Festuca elatior* (1144)	1. *Brachypodium phoenicoides* (1719)
2. *Bromus arduennensis* (2382)	2. *Bromus polyanthus* (2360)	2. *Bromus inermis* (1297)
3. *Festuca Mairei* (1499)	3. *Agropyron intermedium* (1342)	3. *Bromus arduennensis* (2382)
4. *Bromus inermis* (1297)	4. *Bromus arduennensis* (2382)	4. *Agropyron cristatum* (1089)
5. *Brachypodium phoenicoides* (1719)	5. *Brachypodium phoenicoides* (1719)	5. *Agropyron intermedium* (1342)
6. *Dactylis glomerata* (2145)	6. *Oryzopsis miliacea* (1931)	6. *Bromus polyanthus* (2360)
7. *Festuca elatior* (1144)	7. *Dactylis glomerata* (2145)	7. *Agropyron cristatum* (1296)
8. *Bromus inermis* (1967)	8. *Agropyron intermedium* (1358) } equal	8. *Oryzopsis miliacea* (1931)
9. *Agropyron intermedium* (1342)	9. *Bromus inermis* (1297) } equal	9. *Agropyron intermedium* (1358)
10. *Festuca arenaria* (1924)	10. *Phalaris coerulescens* (1306)	10. *Festuca elatior* (1144)
11. *Festuca rubra* var. *genuina* (1295)	11. *Bromus inermis* (1967)	11. *Dactylis glomerata* (2145)
12. *Agropyron cristatum* (1089)	12. *Agropyron cristatum* (1296)	12. *Phalaris stenoptera* (1305)
13. *Agropyron intermedium* (1358)	13. *Festuca Mairei* (1499)	13. *Bromus inermis* (1967)
14. *Agropyron cristatum* (1296)	14. *Festuca arenaria* (1294)	14. *Festuca arenaria* (1294)
15. *Festuca rubra* var. *fallax* (1293)	15. *Agropyron cristatum* (1089)	15. *Phalaris coerulescens* (1306)
16. *Phalaris stenoptera* (1350)	16. *Festuca rubra* var. *genuina* (1295)	16. *Festuca Mairei* (1499)
17. *Phalaris coerulescens* (1306)	17. *Festuca rubra* var. *fallax* (1293)	17. *Festuca rubra* var. *genuina* (1295)
18. *Oryzopsis miliacea* (1931)	18. *Phalaris stenoptera* (1350)	18. *Phalaris stenoptera* (1350)
19. *Phalaris stenoptera* (1305)	19. *Phalaris stenoptera* (1305)	19. *Festuca rubra* var. *fallax* (1293)

* = Commonwealth Plant Introduction Number.

TABLE 3.—ESTIMATED PALATABILITY.

Species.	Average estimate with respect to palatability, based on periodic close observations as to preference or otherwise on the part of sheep for the various grasses.
Agropyron cristatum (C.P.I. 1089)	Decidedly palatable, being readily and well grazed
Agropyron cristatum (C.P.I. 1296)	Decidedly palatable, being readily and well grazed
Agropyron intermedium (C.P.I. 1358)	Decidedly palatable, being readily and well grazed
Agropyron intermedium (C.P.I. 1342)	Decidedly palatable, being readily and well grazed
Brachypodium phoenicoides (C.P.I. 1719)	Fairly palatable, being in general fairly readily and moderately well grazed
Bromus inermis (C.P.I. 1297)	Palatable, being readily and fairly well to well grazed
Bromus inermis (C.P.I. 1967)	Palatable, being readily and fairly well to well grazed
Bromus arduennensis (C.P.I. 2382)	Moderately palatable, being moderately readily and moderately well grazed
Bromus polyanthus (C.P.I. 2360)	Fairly palatable, being in general fairly readily and moderately well grazed
Festuca arenaria (C.P.I. 1294)	Very palatable, being readily and well grazed especially at tender stage
Festuca rubra var. *fallax* (C.P.I. 1293)	Palatable, very palatable in the tender stage, usually well grazed
Festuca rubra var. *genuina* (C.P.I. 1295)	Palatable, very palatable in the tender stage, usually well grazed
Festuca elatior (C.P.I. 1144)	Quite palatable, being readily and closely grazed for a rather coarse grass
Festuca Mairei (C.P.I. 1499)	Quite palatable, being readily and closely grazed for a rather coarse grass
Dactylis glomerata (C.P.I. 2145)	Palatable in winter, when makes most growth; grazed rather tardily at other times of the year
Oryzopsis miliacea (C.P.I. 1931)	Palatable when immature, not particularly palatable at flowering stage, when ordinarily avoided by sheep
Phalaris coerulescens (C.P.I. 1306)	Palatable in winter; at other times of the year the sheep prefer the other grasses, when they consistently graze this grass last
Phalaris stenoptera (C.P.I. 1305)	Palatable in winter; at other times of the year the sheep prefer the other grasses, when they consistently graze this grass last
Phalaris stenoptera (C.P.I. 1350)	Palatable in winter: at other times of the year the sheep prefer the other grasses, when they consistently graze this grass last

Table 4.—Rainfall, at Six Weekly Intervals, at Duntroon Farm (C.S.I.R.), Canberra, F.C.T., During the Period 12th April, 1935, to 25th April, 1936.

Interval.	Points.	Total.
1935—		
12th April to 23rd May	270	
24th May to 4th July	19	
5th July to 15th August	188	
16th August to 27th September	150	
28th September to 8th November	332	
9th November to 21st December	339	
1935–36—22nd December to 1st February ..	348	
1936—		
2nd February to 14th March	536	
15th March to 25th April	243	
		24·25 inches

Note.—100 points = 1 inch.

Table 5.—Grasses Arranged According to the Season of the Year during which the Growth thereof is more Prominent.

Summer.	Late Summer-Early Autumn.	Autumn.	Late Autumn.	Early Winter.
All grasses in test	*Bromus arduennensis* (2382*)	*Bromus arduennensis* (2382)	*Agropyron cristatum* (1089)	*Bromus arduennensis* (2382)
	Bromus polyanthus (2360)	*Bromus polyanthus* (2360)	*Agropyron cristatum* (1296)	*Bromus polyanthus* (2360)
	Dactylis glomerata (2145)	*Festuca elatior* (1144)	*Agropyron intermedium* (1358)	*Dactylis glomerata* (2145)
	Festuca arenaria (1294)	*Festuca rubra* var. *genuina* (1295)	*Brachypodium phoenicoides* (1719)	*Festuca elatior* (1144)
	Oryzopsis miliacea (1931)		*Dactylis glomerata* (2145)	*Festuca Mairei* (1499)
			Festuca rubra var. *fallax* (1293)	*Festuca rubra* var. *fallax* (1293)
			Festuca arenaria (1294)	*Phalaris coerulescens* (1306)
			Festuca rubra var. *genuina* (1295)	*Phalaris stenoptera* (1305)
			Festuca mairei (1499)	*Phalaris stenoptera* (1350

* = Commonwealth Plant Introduction Number.

3. General Discussion and Conclusions.

A perusal of Tables 1 and 2 gives rise to certain conclusions. The best yielding grasses, under all treatments, are *Bromus polyanthus* (C.P.I. 2360), *Bromus arduennensis* (C.P.I. 2382), *Brachypodium phoenicoides* (C.P.I. 1719), *Agropyron intermedium* (C.P.I. 1342), and *Festuca elatior* (C.P.I. 1144). The longer interval associated with both mowing every eight weeks and pasturing closely with sheep as the growth warrants, as compared with mowing every six weeks, increases the annual yield in such grasses as *Oryzopsis miliacea* (C.P.I. 1931) and *Agropyron intermedium* (C.P.I. 1358). Pasturing as the growth warrants increases the annual yield in *Phalaris stenoptera* (C.P.I. 1305) due primarily to its not being specially palatable to sheep, while the same treatment decreases the annual yield in such grassess as *Festuca Mairei* (C.P.I. 1499) and *Festuca elatior* (C.P.I. 1144), due to their being particularly palatable to sheep and thus possessing a tendency to be very closely grazed. Grasses which on the average yield well or reasonably well in the colder portion of the year include *Bromus polyanthus* (C.P.I. 2360), *Bromus arduennensis* (C.P.I. 2382), *Festuca elatior* (C.P.I. 1144), *Festuca Mairei* (C.P.I. 1499), *Dactylis glomerata* (C.P.I. 2145) (strain), *Phalaris coerulescens* (C.P.I. 1306), *Phalaris stenoptera* (C.P.I. 1305), and *Phalaris stenoptera* (C.P.I. 1350).

On the whole, Treatment (C) (pasturing closely with sheep as the growth warrants) was more exacting on the swards, from the standpoint of promoting yield, as compared with the mowing treatments; and this was particularly noticeable in the cases of the most palatable grasses.

The relatively good showing associated with *Agropyron cristatum* (C.P.I. 1089), *Agropyron cristatum* (C.P.I. 1296), and *Brachypodium phoenicoides* (C.P.I. 1719 B) under Treatment (C) is partly accounted for by the fact that these were end plots where the sheep tended to camp, which camping promoted the growth of barley grass on the two first-named and closely-grazed plots and rank growth on the last-named and usually incompletely-grazed plot.

For the history of the introduction and a brief description of the grasses referred to in this paper, the reader is referred to C.S.I.R. Pamphlet No. 59 ("A Study of Persistence in Certain Introduced Pasture Grasses").

4. Acknowledgments.

In the obtaining and preparation of the data contained herein, I acknowledge the help rendered by various Sectional assistants, including Mr. W. Hartley, B.A. (Assistant Research Officer). My thanks are also due to Miss F. E. Allan, M.A., Biometrician, for the rainfall data obtained at the Duntroon Farm (C.S.I.R.), meteorological station.

KEY TO GRASSES REPRESENTED IN HISTOGRAMS.

(From left to right.)

1. *Agropyron cristatum* (C.P.I. 1089)
2. *Agropyron cristatum* (C.P.I. 1296)
3. *Agropyron intermedium* (C.P.I. 1358)
4. *Agropyron intermedium* (C.P.I. 1342)
5. *Brachypodium phoenicoides* (C.P.I. 1719) (ave. of two plots)
6. *Bromus inermis* (C.P.I. 1297)
7. *Bromus inermis* (C.P.I. 1967)
8. *Bromus arduennensis* (C.P.I. 2382)
9. *Bromus polyanthus* (C.P.I. 2360)
10. *Festuca arenaria* (C.P.I. 1294)
11. *Festuca rubra var. fallax* (C.P.I. 1293)
12. *Festuca rubra var. genuina* (C.P.I. 1295)
13. *Festuca elatior* (C.P.I. 1144)
14. *Festuca Mairei* (C.P.I. 1499)
15. *Dactylis glomerata* (C.P.I. 2145)
16. *Oryzopsis miliacea* (C.P.I. 1931)
17. *Phalaris coerulescens* (C.P.I. 1306)
18. *Phalaris stenoptera* (C.P.I. 1305)*
19. *Phalaris stenoptera* (C.P.I. 1350)*

* *P. stenoptera* is a strain of *P. tuberosa*.

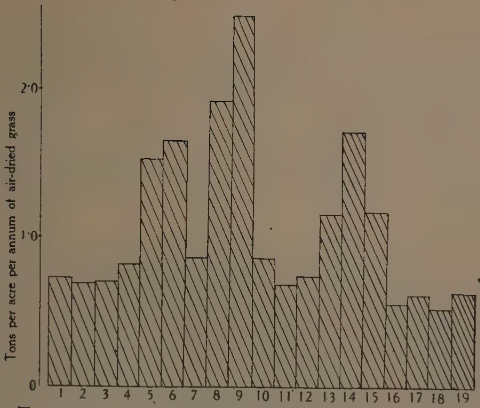

Fig. 1.—Yields from swards of introduced grasses. Treatment (A).

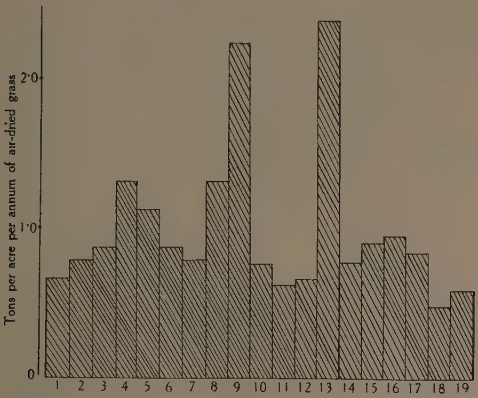

Fig. 2.—Yields from swards of introduced grasses. Treatment (B).

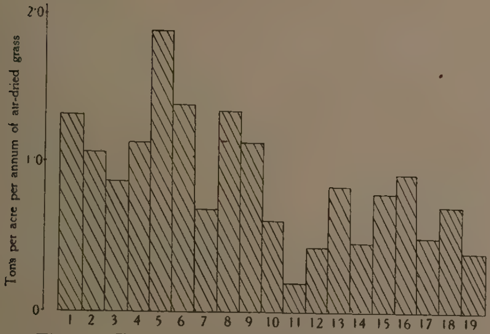

Fig. 3.—Yields from swards of introduced grasses. Treatment (C).

A Chemical Examination of *Sarcostemma australe*, R.Br., the "Caustic Vine."

By J. C. Earl, D.Sc., Ph.D., and J. P. Doherty, B.Sc.†*

Sarcostemma australe, R.Br. is a latex-bearing plant belonging to the Natural Order Asclepiadaceae and is found growing in the interior of Australia. It has been reported as poisonous to stock, and an examination by Gilruth and Murnane (this *Journal,* **4**: 225, 1931) definitely established its toxicity. The poisonous principle was found by the same workers to be soluble in water or alcohol but insoluble in petroleum ether.

A closer chemical study of the plant has now been undertaken, and some of its constituents identified. Thorough kneading of the air-dried, ground, plant material with cold alcohol extracted from it, besides the toxic principle, a quantity of waxy substances (cf. Smith, *J. Roy. Soc. N.S.W.,* **56**: 183, 1922). The waxy part of the mixture remaining after evaporating the alcoholic solution was dissolved away by means of ether, leaving a substance which had the general characteristics of a saponin. It dissolved readily in cold water and gave a solution which, on shaking, produced a lasting froth. Purification of the saponin was readily effected by taking advantage of its sparing solubility in hot water. An aqueous solution prepared by dissolving the crude saponin in cold water separated into two layers on heating, the lower syrupy layer containing almost all the saponin. The upper layer, containing impurities soluble in water, was decanted off, the lower being re-dissolved in cold water and re-precipitated by heating the solution as before.

The saponin so isolated was obviously glucosidic in character, and *a*-methyl glucoside was isolated as one of the products of its decomposition by heating with methyl alcoholic hydrochloric acid. Analysis indicated the composition $C_{22}H_{34}O_{10}$ for the substance, but, in the absence of any criteria of purity, no great value can be attached to this result. A further detailed examination of the saponin is in progress.

The waxy material dissolved in ether during the isolation of the saponin was examined after removal of solvent. It contained about 30 per cent. of unsaponifiable matter from which a crystalline material could be separated comparatively easily. It was obvious, however, that the material was a complex mixture. After a number of attempts to separate individual constituents in a pure state by fractional crystallization from solvents, it was found advantageous to acetylate the whole by boiling with acetic anhydride and to separate the resulting acetates by systematic fractional crystallization from ethyl acetate. In this way,

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two crystalline acetates were isolated and were identified with the acetates of α- and β- amyrin, two isomeric alcohols which have been recorded as occurring in elemi resin and in a number of other natural products.

The other substances contained in the waxy material appeared to be chemically inert and did not react with such reagents as potassium permanganate, bromine in carbon tetrachloride, &c.

Experimental.

Isolation of the Saponin.—The powdered dried plant (550 grams) was agitated for several hours in a porcelain ball mill with methylated spirit (1320 ml.). After removal of the solution by filtration, the residue was treated with successive quantities of 1000 ml. and 500 ml. of spirit. The combined alcoholic extracts were evaporated to a syrup which was kneaded repeatedly with successive quantities of ether, about 200 ml. in all. The saponin was then dissolved in cold water, and the solution (volume 110 ml.) filtered. The clear solution was heated in a water-bath at 90-95° C. until there was a clear separation into two layers. The upper layer was decanted as completely as possible and the lower one re-dissolved in cold water (40 ml.). Heating and separation into two layers was repeated. The syrupy product was dissolved in spirit and evaporated to dryness on a boiling water-bath. This treatment was repeated several times to free the material as far as possible from water. Finally, the product was ground to a powder under ether and dried. The weight of saponin at this stage was 13.0 grams.

Carbon found 57.7, 57.3 per cent.

Hydrogen found 7.6, 7.7 per cent.

$C_{22}H_{34}O_{10}$ contains carbon 57.6, hydrogen 7.5 per cent.

Examination of the Waxy Material.—The ethereal solution obtained during the extraction of the saponin from approximately 6 kg. of the dry vine was evaporated, and the residue dried at 110°C. for 2½ hours. During the last half-hour of heating, there was no appreciable loss in weight. The product was a dark-green pitch and weighed 375 grams, i.e., 6.25 per cent. of the original vine.

The material had a saponification value of 108, an acid value of 22, and an iodine value of 45, when examined by the usual analytical methods. The percentage of unsaponifiable matter was 29.6, and part of it crystallized from petroleum ether. Attempts to isolate pure constituents by crystallization from petroleum ether were not very successful, as the fractions isolated did not have sharp melting points. Better separation was obtained by acetylating the material prior to fractional crystallization. The crude unsaponifiable matter (20 grams) was acetylated by heating with excess of acetic anhydride for 2 to 3 hours in a boiling water-bath. On cooling, a crystalline material separated out and was filtered off (6.7 grams). Fractional crystallization of this material from ethyl acetate led to the isolation of two definite substances, one melting at 233°C. (1.6 grams) and the other at 217°C. (2.4 grams). Further purification raised the melting points to 235-6°C. and 218-220°C., respectively.

The analyses and characteristics of the two amyrin acetates isolated from elemi resin as recorded in the literature are given in the following table in comparison with the observations made on the two abovementioned substances:—

——	α Amyrin Acetate.	Product from *Sarcostemma*.	β Amyrin Acetate.	Product from *Sarcostemma*.
Carbon	82·0*	82·2	82·0*	82·3
Hydrogen	11·2*	11·5	11·2*	11·5
Molecular weight (cryoscopic in benzene)	468*	511	468*	507
Melting Point	221° C.	218–220° C. (uncorr.)	236° C.	235–6° C. (uncorr.)
$[\alpha]_D$ in benzene	+ 77° (17·6° C.)	+ 76·6° (15° C.)	+ 78.6° (16·7° C.)	+ 81·6° (15° C.)
Molecular weight calculated from saponification value ..	468*	463	468*	461

The correspondence with the amyrins is also shown by the free alcohols formed on saponifying the acetates.

——	α Amyrin.	Product from *Sarcostemma*.	β Amyrin.	Product from *Sarcostemma*.
Carbon	84·4*	84·5	84·4*	84·2
Hydrogen	11·8*	12·1	11·8*	12·0
Melting Point	181–181·5° C.	180–182° C.	193–194° C.	191–192° C.

* Values calculated from the accepted formula for the amyrins.

There can be no doubt that the two amyrins are present in *Sarcostemma australe*.

The investigation was initiated by the Poison Plants Committee* of the Council for Scientific and Industrial Research, which also procured the necessary material; it was continued after the Council, owing to restriction in its funds, was no longer able to give any financial support to the Committee. Most of the determinations of carbon and hydrogen recorded in the paper were made by Miss E. Goulston, B.Sc., Demonstrator in Micro-analysis in the University of Sydney.

* A Committee in the work of which the University of Sydney, the New South Wales Department of Agriculture, and the Council for Scientific and Industrial Research were co-operating.

"Included Sapwood" in Karri (*E. diversicolor*).

*By J. E. Cummins, M.Sc.**

1. Introduction.

"Included sapwood," as its name implies, is virtually sapwood which has been included by and in the truewood. In dark-coloured woods it is generally visible as a light-coloured patch or streak. It is frequently found in Australian timbers, being much more general in some species than in others. It is also recorded in overseas timber and is quite commonly found, for example, in pencil cedar (*Juniperus virginiana*).

In karri (*E. diversicolor*), "included sapwood" is of frequent occurrence, and, as it is associated with borer damage in the living tree and is often discoloured, the question of its inclusion in structural material is one of some importance. The Conservator of Forests. Western Australia, requested that an examination be made of a number of samples of karri containing "included sapwood," and this report deals with the experimental work carried out on these specimens, the work involving the following:—

(*a*) the preparation of thin sections and their examination, under the microscope, for fungi,

(*b*) attempts to culture any fungi which might be present in the wood, and

(*c*) toughness tests on material containing "included sapwood" and comparative tests on normal truewood.

2. Material for Test.

The material for test consisted of twelve pieces of green karri about $2\frac{1}{2}$ inches by $2\frac{1}{2}$ inches by 3 inches, this material having been collected from five different trees. Four of the samples came from the one tree, two from the butt log and two from the top log. In nearly all cases, insect borings were evident in the regions of "included sapwood," which was present in nine of the samples forwarded.

3. Microscopical Examination.

Small blocks of "included sapwood" and the adjoining truewood were cut from the specimens and, where considered desirable, from several positions in the one specimen. The blocks were sectioned, and the sections stained for the presence of fungal hyphae using Cartwright's method†.

Detailed examination of the sections showed that in all cases of "included sapwood" there were abundant fungal hyphae. The hyphae were mostly very thick, septate, and much branched, and characteristic

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† A satisfactory method of staining fungal mycelium in wood sections, by K. St. G. Cartwright. *Ann. Bot.* 43: April, 1929.

of "sap-staining" fungi. In several cases, however, hyphae of basidiomycete or wood-destroying fungi were present. Sometimes also, there was an extension of the fungal hyphae to the truewood, but this extension was very restricted in amount.

It is worth noting that examination of the cleanly cut cross-section of "included sapwood" areas using a hand lens of ten magnifications disclosed that the pores or vessels were always open, no tyloses having developed. This is in direct contrast to the truewood which is heavily tylosed, all the pores therein containing cell wall ingrowths, which appear as blockages of the lumen of the vessels. This feature can also be seen distinctly with the naked eye on a cleanly cut cross-section and can be used as a diagnostic feature for "included sapwood."

4. Pathological Examination.

Small chips of "included sapwood" were removed under sterile conditions from the various specimens containing the "included sapwood," and these chips were partly set in a medium of malt-agar contained in culture tubes. The tubes were then incubated at about 25°C. for periods up to two months, examination of the tubes being made at periodical intervals.

In no case did fungal hyphae develop, either on the chips or on to the medium, thus indicating that the fungi disclosed by the microscopical examination, were dead.

5. Mechanical Tests.

Toughness specimens $\frac{5}{8}$ inch by $\frac{5}{8}$ inch by 10 inches long were cut from the samples supplied, as much "included sapwood" as possible being included in individual specimens containing this "defect." Control specimens were cut from adjacent truewood.

An examination of the specimens after breaking indicated that there was little difference, if any, between specimens with and without "included sapwood," the type of fracture being similar in all cases, namely, tough. Sap-staining fungi do not seriously affect the strength of wood, and this result is, therefore, consistent with the general type of fungal infection found.

6. Examination of Associated Borer Holes.

Examination of the borer holes present in the samples supplied showed that these were only of limited length. Where "included sapwood" occurred, they often extended deeper into the tree, but in no case did they extend further out towards the bark than the outer extent of the "included sapwood." This observation has previously been made in the field.

7. Discussion.

Examinations of the borer holes present in the "included sapwood" and the evidence given above appear to indicate the following as being the sequence of fungal development in the "included sapwood."

Apparently, owing to periods of "drought" or other factors non-conducive to active tree growth, or even to the occurrence of injuries to the trunk caused, for example, by fire or abrasion, insects attack the growing tree, penetrating into the sapwood, and extending in some cases to the truewood. Mechanical injury to the sapwood cells adjacent to the boring apparently results in the development of some condition bringing about partial or complete death of the living sapwood cells, preventing their subsequent development into truewood.

The fungal infection is no doubt introduced directly on the body of the borer either as spores or mycelial fragments. When infection first occurs, conditions are suitable for fungal development, although apparently only at a slow rate. This fungal development continues until the moisture-air relations in the "included sapwood" become unsatisfactory, this being caused by the inclusion of the infected wood under layers of newer wood laid down on the outside of it. As soon as this occurs, fungal growth ceases. The viability of fungi varies considerably. Some studies have indicated that *Trametes lilacino-gilvus* Berk remained viable in wood for a period of at least seven years, when the wood was kept under dry conditions. Under similar conditions, *Merulius lachrymans* remained viable for a period of five years, while sporophores under similar conditions only remained viable for three years.* Other investigators have reported upon the viability of spores of various fungi, but the times obtained, even under good conditions of storage, have not exceeded a few years. Included sapwood in a karri tree is seldom less than five years old, if only newly formed, and is usually considerably older. None of the samples of fungal infected "included sapwood" contained viable mycelium or secondary spores.

Although all these specimens of "included sapwood" were at least 20 years old, it is reasonable to assume that viable fungi will seldom be found in freshly converted "included sapwood."

Finally, ordinary "included sapwood" can be considered to be as strong as normal truewood. Being fundamentally sapwood, however, its natural durability is less than truewood. Unless obviously decayed, the fungal infection present in "included sapwood" can be discounted, the fungi being dead; the material can, therefore, be looked upon as being virtually ordinary sapwood. When used under conditions conducive to decay development, the "included sapwood" can be considered as a potential source of danger, as such areas are more prone to infection than the truewood and they may very well serve as centres of infection. However, untreated karri is not advocated for use under conditions where decay may develop, and for such purposes, therefore, "included sapwood" should not be considered a defect, unless natural colour, as in flooring, is a factor. For special purposes such as wood pipe stock, however, "included sapwood" is a defect, as it permits liquid movement due to the open pores, thus causing "weeping" in the finished pipe line.

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* A. McCrea, *Mycologia* **26**: 454, 1934.

8. Conclusions.

1. "Included sapwood" is generally found to have been attacked by fungi of the "sap staining" form. All the fungi are dead, death having occurred in the living tree.

2. There is no significant difference between the strength of normal "included sapwood" and truewood.

3. Normal "included sapwood" is not considered to be a defect in structural material when this is used under conditions which are not conducive to the development of decay.

4. For special purposes such as wood pipe stock "included sapwood" is definitely a defect.

5. "Included sapwood" appears to be always associated with borer development in the living tree.

Note.—The above conclusions are based on tests of a limited number of specimens, and it may be considered desirable to extend the testing. Considerable experience in the handling of karri, however, leads the author to believe that it is reasonable to expect similar results from other material.

The Relation between Air Flow and Pressure Change across a Stack of Timber.

*By W. L. Greenhill, M.E.**

The article that follows is the fourth of a series on kiln aerodynamics; the previous three articles appeared in the May, August, and November, 1936, issues respectively.—Ed.

Summary.

The flow of air through a rectangular duct consisting of boards and separating strips, and similar to the openings through a timber stack, has been investigated. The relation has been established between static pressure change and rate of air flow using strips of different thickness and boards with surfaces of different degrees of roughness.

1. Introduction.

The question of quantity of air required to be circulated through a stack of timber in a seasoning kiln has been discussed in the third article of this series; the resistance to air flow to be overcome in providing this circulation forms the subject of the present article. The fan or fans installed must be chosen to deliver the required quantity of air against this resistance.

Obviously, the thickness of separating strips used in the construction of a stack of timber of fixed overall dimensions is of primary importance, as it affects the number of openings through the stack and thus the total quantity of air required as well as the resistance to be overcome. The most efficient size of strip to be used must be decided from economic considerations involving the advantages of increased kiln capacity with reduction of strip size as against the cost of increased power necessary to drive the required quantity of air through the smaller openings between boards. Commercial practice has indicated that, with the size of kilns commonly used in Australia in which the stacks are from 5 to 6 feet wide, the most efficient size of strip is generally between $\frac{5}{8}$ inch and $\frac{7}{8}$ inch thick.

2. Apparatus.

Kiln.—The main item of equipment for the present tests was the experimental kiln designed for this class of work and described previously (4). In this kiln a rectangular duct 6 feet long and 18 inches wide was built up with 4-inch wide boards and separating strips, and air at various velocities was driven through the duct. Separating strips $\frac{3}{8}$-inch, $\frac{1}{2}$-inch, $\frac{5}{8}$-inch, $\frac{3}{4}$-inch, $\frac{7}{8}$-inch, 1-inch, $1\frac{1}{4}$-inch, and $1\frac{1}{2}$-inch were used in turn and, with each size of strip, tests were made with boards of three different degrees of roughness. These are shown in Fig. 1, and may be described as (*a*) smooth (planed), (*b*) average sawn, and (*c*) rough sawn. Care was taken to ensure that the air passed only through the duct, the outside of which was sealed with strong paper to prevent leakage between boards.

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Anemometer.—The velocity of the air passing through the duct was measured at the exit end using the anemometers and method described in the first article of this series and applying correction figures as for 2-inch thick timber, that is, where only one opening admits air to the anemometer.

FIG. 1.—Types of surfaces used :
(*top*) smooth,
(*centre*) average sawn,
(*bottom*) rough sawn.
(The boards illustrated above are about one quarter their original size.)

Pressure Tubes and Manometer.—Static pressure tubes were located in each of the following positions:—

(i) In the open kiln chamber outside the entrance to the duct.
(ii) In the duct 6 inches from the entrance end.
(iii) In the duct 6 inches from the exit end.

The static tubes used were of the hemispherical end type similar in external shape to the pitot tube described by Ower (5). As, however, the tubes were required to measure static pressure differences only and not air velocities, the hemispherical end of the tube was made solid as shown in Fig. 2.

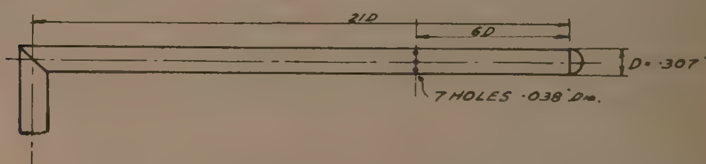

FIG. 2.—Type of tube used in measuring static pressures.

The manometer employed for the static pressure difference measurements was of the direct lift type shown in Fig. 3. In this, a large spun brass reservoir forms one leg of the U-tube, and is connected through rubber tubing to a short length of glass tubing mounted on a metal bracket at a small angle to the horizontal. The bracket is carried by a block which can be raised or lowered by means of a micrometer screw and dial. The gauge is filled with coloured alcohol whose specific gravity must be accurately determined.

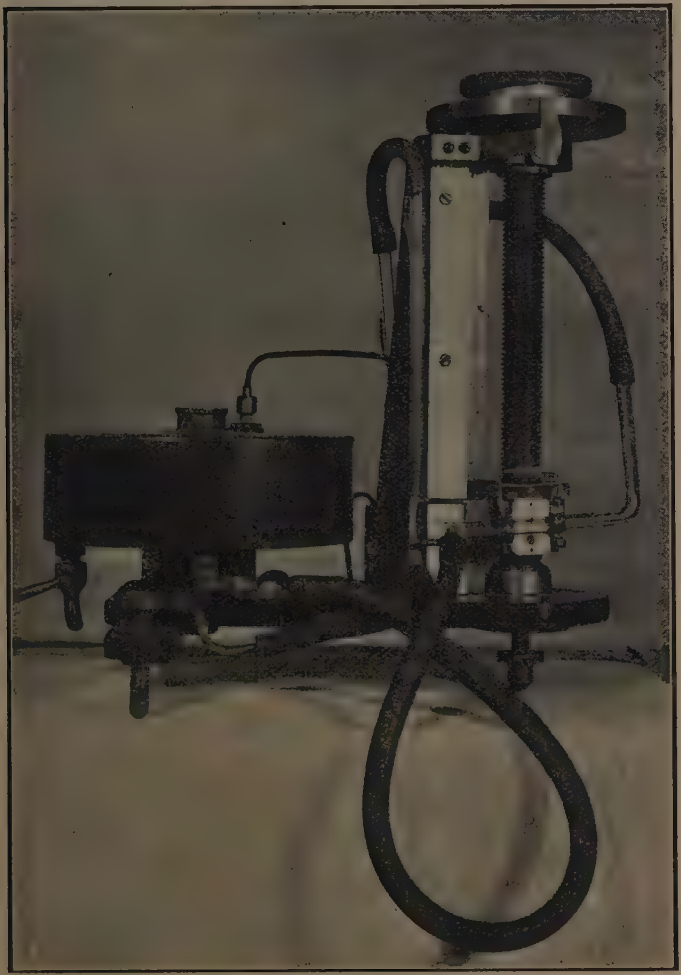

Fig. 3.—Manometer Used.

The meniscus in the slanting tube, with the gauge at zero, is adjusted by a small screw which raises or lowers the tube independently of the micrometer screw until the meniscus is tangent to a hair line engraved on the glass.

Under the action of the applied pressure difference, the alcohol tends to rise in the slanting tube, and the tendency is counteracted by raising the tube bodily by means of the micrometer screw, keeping the meniscus tangent to the hair line. The amount the tube is elevated is then the pressure difference in inches of alcohol. The sensitivity of the gauge can be varied by adjusting the slope of the inclined tube.

This manometer is evidently a self standard whose precision depends only on the accuracy of the micrometer screw. The use of the large reservoir renders it necessary to observe one meniscus only.

3. Procedure.

Ducts were constructed using in turn the different sized separating strips and with boards of the different degrees of roughness. In each set-up a series of velocity and pressure difference readings were taken with 6 different air velocities, the velocity being varied by changing the fan speed and, where necessary, baffling the fan intake. Approximately the same set of fan speeds and baffles were used in each test.

The velocity was computed each time from the average of four anemometer readings taken across the width of the duct. The particular anemometer used depended on the air velocity to be measured, and readings were made in each case by timing with a stop-watch the period required for the instrument to record 100 feet.

Static pressure differences were measured as follows:—

(*a*) between the two tubes 5 feet apart in the duct, and

(*b*) between the tube outside the duct on the entering air end and the tube in the duct $5\frac{1}{2}$ feet from the entering air end.

From (*a*) the change in pressure per foot of duct was obtained $\left(=\frac{a}{5}\right)$, and from (*b*) and (*a*) the entrance pressure loss was determined $\left(=b-\frac{5\frac{1}{2}a}{5}\right)$.

4. Results.

The results are given in Table 1. The anemometer readings have been corrected so that actual air velocities are given and pressure results are in inches of water, the gauge readings having been multiplied by the specific gravity of the alcohol in the instrument.

TABLE 1.

Size of Separating Strips.	Results of Tests with Planed Boards.			
	Air Velocity (feet per minute).	Pressure Loss per Foot of Duct.	Entrance Pressure Loss.	Ratio— $\frac{\text{Entrance Pressure Loss}}{\text{Velocity}^2}$.
In.				
$\frac{3}{8}$	2,154	·0685	·209	4·5 x 10^{-8}
	1,828	·0485	·137	4·1
	1,196	·0210	·060	4·2
	1,079	·0171	·050	4·3
	733	·0078	·0235	4·4
$\frac{1}{2}$	2,118	·0562	·205	4·3 x 10^{-8}
	1,770	·0391	·125	4·0
	1,191	·0181	·067	4·7
	914	·01	·0375	4·5
	668	·0056	·019	4·3
$\frac{5}{8}$	2,218	·0544	·234	4·5 x 10^{-8}
	1,811	·0355	·161	4·9
	1,276	·0177	·068	4·2
	1,089	·0133	·050	4·2
	750	·0059	·025	4·5
	549	·0033	·013	4·3
$\frac{3}{4}$	2,280	·0510	·229	4·4 x 10^{-8}
	1,722	·0281	·118	4·0
	1,225	·0141	·070	4·7
	1,026	·0106	·048	4·6
	832	·0063	·031	4·5
	486	·0024	·010	4·2
$\frac{7}{8}$	2,344	·0461	·226	4·1 x 10^{-8}
	1,710	·0259	·123	4·2
	1,169	·0115	·067	4·9
	955	·0072	·038	4·2
	614	·0033	·017	4·5
	428	·0016	·0075	4·1
1	2,239	·0407	·195	3·9 x 10^{-8}
	1,660	·0213	·104	3·8
	1,148	·0106	·063	4·8
	851	·0056	·033	4·6
	552	·0023	·013	4·3
	352	·0010	·0055	4·5
$1\frac{1}{4}$	2,148	·0325	·199	4·3 x 10^{-8}
	1,560	·0172	·092	3·8
	1,112	·0139	·050	4·0
	826	·0045	·028	4·1
	472	·0015	·009	4·1
	304	·0006	·004	4·3
$1\frac{1}{2}$	1,928	·0230	·148	4·0 x 10^{-8}
	1,445	·0132	·090	4·3
	984	·0059	·0425	4·4
	698	·0025	·019	3·9
	378	·0009	·0065	4·6
	243	·0004	·0025	4·2

TABLE 1—*continued.*

Size of Separating Strips.	Results of Tests with Average Sawn Boards.			
	Air Velocity (feet per minute).	Pressure Loss per Foot of Duct.	Entrance Pressure Loss.	Ratio—$\frac{\text{Entrance Pressure Loss}}{\text{Velocity}^2}$.
In.				
3/8	2,163	·0912	·220	$4·7 \times 10^{-8}$
	1,730	·0586	·138	4·6
	1,268	·0305	·072	4·5
	1,112	·0239	·058	4·8
	944	·0170	·039	4·4
	773	·0112	·0245	4·1
1/2	2,178	·0755	·184	$3·9 \times 10^{-8}$
	1,652	·0432	·120	4·4
	1,250	·0239	·065	4·2
	1,074	·0178	·048	4·2
	863	·0118	·032	4·3
	586	·0056	·017	4·9
5/8	2,198	·0660	·212	$4·4 \times 10^{-8}$
	1,738	·0394	·145	4·8
	1,274	·0222	·068	4·2
	968	·0128	·043	4·6
	708	·0068	·0215	4·3
	535	·0038	·019	4·7
3/4	2,249	·0617	·222	$4·4 \times 10^{-8}$
	1,660	·0339	·118	4·3
	1,312	·0206	·079	4·6
	1,028	·0112	·045	4·3
	658	·0051	·0195	4·5
	443	·0023	·009	4·6
7/8	2,244	·0546	·222	$4·4 \times 10^{-8}$
	1,552	·0266	·113	4·7
	1,202	·0151	·058	4·0
	951	·0099	·041	4·5
	646	·0044	·0195	4·7
	425	·0020	·008	4·5
1	2,203	·0490	·209	$4·3 \times 10^{-8}$
	1,718	·0282	·124	4·2
	1,096	·0120	·046	3·8
	923	·0081	·037	4·4
	528	·0027	·013	4·7
	347	·0012	·0055	4·6
1¼	2,042	·0347	·192	$4·6 \times 10^{-8}$
	1,560	·0205	·092	3·8
	1,099	·0101	·054	4·5
	828	·0058	·031	4·5
	463	·0017	·0095	4·4
	302	·0007	·004	4·4
1½	1,820	·0251	·119	$3·6 \times 10^{-8}$
	1,374	·0141	·073	3·9
	989	·0073	·041	4·2
	695	·0034	·019	4·0
	452	·0016	·008	4·0
	263	·0005	·003	4·3

TABLE 1—*continued.*

Size of Separating Strips.	Results of Tests with Rough Sawn Boards.			
	Air Velocity (feet per minute).	Pressure Loss per Foot of Duct.	Entrance Pressure Loss.	Ratio— $\frac{\text{Entrance Pressure Loss}}{\text{Velocity}^2}$.
In.				
3/8	1,888	·0832	·142	$4·0 \times 10^{-8}$
	1,552	·0562	·113	4·7
	1,086	·0262	·059	5·0
	908	·0189	·0395	4·8
	730	·0110	·0245	4·6
1/2	1,977	·0752	·156	$4·0 \times 10^{-8}$
	1,574	·0474	·119	4·8
	1,030	·0206	·042	4·0
	836	·0134	·033	4·7
	627	·0076	·0195	4·8
5/8	2,014	·0676	·174	$4·3 \times 10^{-8}$
	1,578	·0412	·114	4·6
	1,127	·0219	·065	5·1
	955	·0152	·042	4·6
	708	·0088	·020	4·0
	520	·0045	·013	4·8
3/4	2,004	·0608	·156	$3·9 \times 10^{-8}$
	1,549	·0366	·098	4·1
	1,054	·0170	·0445	4·0
	904	·0126	·0335	4·1
	655	·0065	·019	4·4
	443	·0030	·009	4·6
7/8	1,968	·0557	·146	$3·9 \times 10^{-8}$
	1,614	·0372	·117	4·5
	1,072	·0162	·055	4·8
	925	·0120	·0375	4·4
	514	·0037	·0105	4·0
	398	·0022	·0075	4·7
1	1,936	·0496	·161	$4·3 \times 10^{-8}$
	1,514	·0300	·096	4·2
	1,057	·0144	·051	4·6
	783	·0082	·0265	4·3
	347	·0016	·005	4·2
1 1/4	1,936	·0436	·164	$4·4 \times 10^{-8}$
	1,507	·0276	·109	4·8
	1,007	·0120	·0455	4·5
	776	·0070	·028	4·7
	433	·0021	·009	4·8
	279	·0010	·0035	4·5
1 1/2	1,871	·0382	·182	$5·2 \times 10^{-8}$
	1,413	·0221	·098	4·9
	1,000	·0109	·041	4·1
	607	·0040	·015	4·1
	366	·0014	·0065	4·9
	209	·0005	·002	4·6

5. Discussion of Results.

Pressure Loss in Duct.—The logarithm of the velocity has been plotted against the logarithm of the pressure loss per foot length of duct for the three types of surfaces in Figs. 4, 5, and 6, respectively. It will be seen that the points for each size of duct fall very closely to a straight line. Evidently, the relation between the velocity (V) and the pressure loss per foot (h) can be expressed in the form:

$$h = kV^n \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where k and n are constants.

Equation (1) can be written:

$$\log h = \log k + n \log V.$$

which is the equation of a straight line inclined at an angle θ to the axis of $\log V$ (where $\tan \theta = n$) and cutting off an intercept equal to $\log k$ on the axis of h. An examination of the curves will show that n is very close to 2 in all cases, while k varies with the size of duct and can be expressed closely as a function of the mean hydraulic depth, that is $\frac{AB}{2(A+B)}$, where A is the length of the longer and B is the length of the shorter side. A is large compared with B, however, and the mean hydraulic depth can be expressed approximately as $\frac{B}{2}$.

If $\log k$ be plotted against $\log B$ for the three different surfaces, the curves are nearly parallel straight lines, and the relation can be expressed as—

$$k = fB^m \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where f and m are constants for any one type of surface. In the present tests, m was found to be close to (—0.61) for the three cases.

Combining (1) and (2) and substituting the values for m and n, we have:

$$h = fB^{-0.61}V^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

For smooth surfaces .. .. $f = 8.05 \times 10^{-9}$

For average sawn surfaces .. .. $f = 10.0 \times 10^{-9}$

And for rough sawn surfaces .. $f = 12.2 \times 10^{-9}$

(B is in inches, V in feet per minute, and h in inches of water per foot length of duct).

Equation (3) is a modification of the well-known Chezy formula for isothermal turbulent flow in straight pipes.

Critical Velocity.—There is no indication from the velocity pressure curves obtained of any change from turbulent to streamline flow which would be evidenced by a change in the slope of the curve. Apparently, the lowest velocities used in the test were still above the critical value.

It is difficult to estimate the critical velocity for the flow of air through ducts, such as the openings through timber stacks, because of the short length of the duct and the effect of entrance disturbances. From the results of Cornish (2), it is estimated that, with the type of duct used in these tests, entrance disturbances would cause a departure from what would otherwise be streamline flow up to a distance of 50 feet from the entrance.

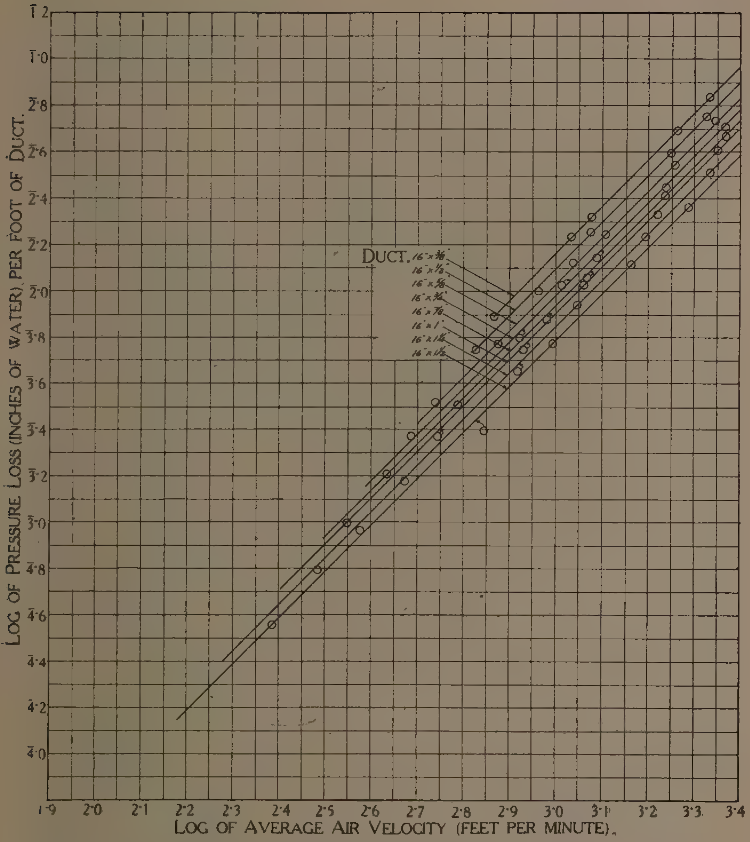

FIG. 4.—Relation between air velocity and pressure loss in ducts constructed of boards with smooth surfaces.

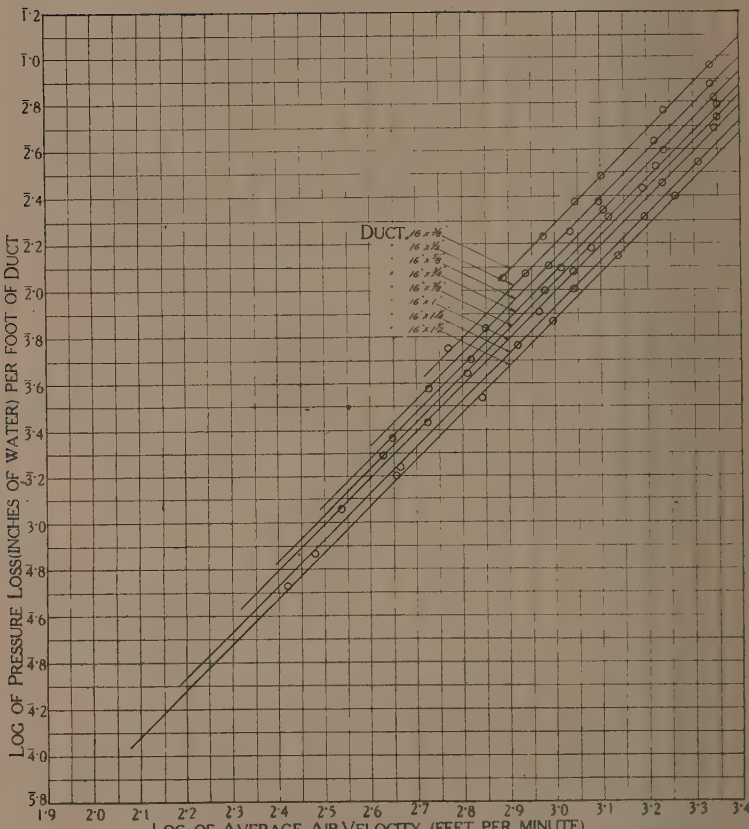

FIG. 5.—Relation between air velocity and pressure loss in ducts constructed of boards with average sawn surfaces.

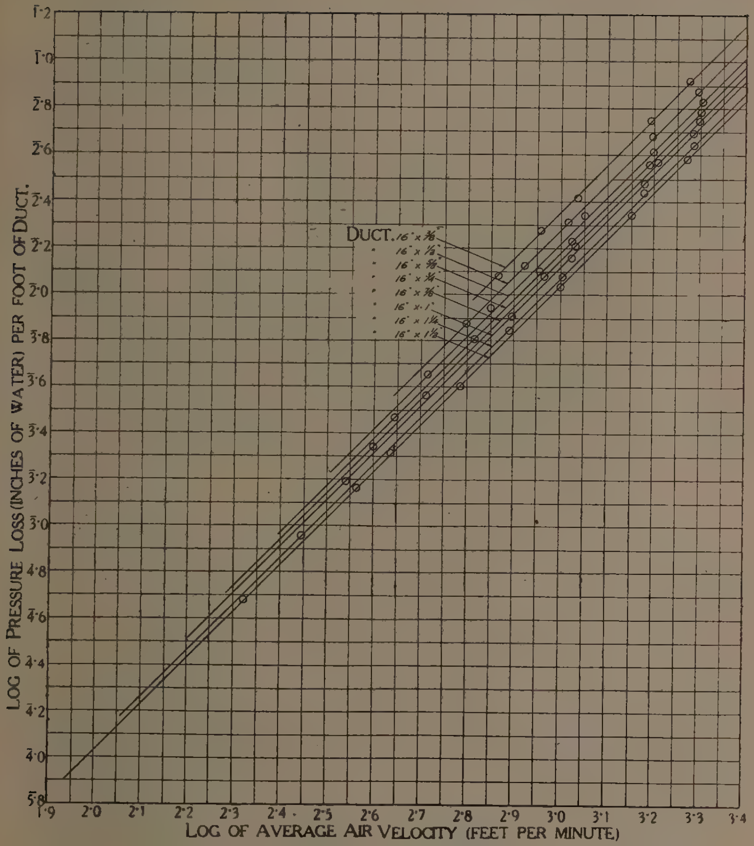

FIG. 6.—Relation between air velocity and pressure loss in ducts constructed of boards with rough surfaces.

The intersections of the experimental curves shown in Figs. 4, 5, and 6, with the theoretical curves for streamline flow, plotted from the equation derived by Greenhill (3) for rectangular ducts, give critical velocities which are almost certainly too high. However, except in the case of the $\frac{3}{8}$-inch duct with planed boards, the experimental curves have been discontinued at the points where the theoretical streamline flow curves would intersect them. In the exception noted, the experimental data actually show the turbulent flow to extend beyond this point.

In the second article of this series, the suggestion was made that the critical velocity may correspond with the minimum velocity above which the drying rate is independent of the velocity. With $\frac{7}{8}$-inch strips and a narrow stack, this velocity was in the neighbourhood of 120 feet per minute. There is no evidence from these later tests to contradict this opinion, but, if the velocity in question does correspond with the critical velocity, it will vary considerably with size of strip as well as with roughness of surface of the boards.

Entrance Loss to Duct.—The pressure loss at the entrance to the opening has been given in Table 1, and also the ratio $\frac{\text{entrance loss}}{V^2}$. It will be seen that this ratio is approximately a constant and may be taken as 4.4×10^{-8}.

Total Pressure Loss across Timber Stack.—A timber stack can be considered as consisting of a number of rectangular ducts in parallel. The total pressure loss across the stack is the sum of the entrance loss and the friction loss in any one duct, and is expressed by:

$$H = (flB^{-0.61} + 4.4 \times 10^{-8})V^2 \quad . \quad . \quad . \quad . \quad (4)$$

where $l =$ width of stack in feet.

The total head against which a kiln fan must operate is the velocity head and the total resistance head. The velocity head (1) can be expressed approximately as $\left(\frac{V}{4005}\right)$. The total resistance head consists mainly of the total pressure loss across the timber stack. Other resistance losses occur in the kiln as the air is conducted from the fan to one side of the stack and returned on the other. The extent of these losses will depend on the kiln design; they will be very small in the cross shaft type of internal fan kiln, somewhat greater in the longitudinal shaft type in which extensive baffles are used, and greater still in external fan types of kilns.

6. References to Literature.

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A Note on Electrodes for Measurement of pH.

*By Arthur R. Riddle, A.B., M.S.**

The work described in the article that follows forms part of the programme which is being carried out by the Council's Section of Food Preservation and Transport in co-operation with the Queensland Meat Industry Board. The lines of that co-operation and some details regarding the programme itself have been given in a previous issue (this *Journal* 5: 133, 1932). Briefly, the Meat Industry Board has provided the buildings and equipment for the Section's laboratory at the Brisbane Abattoir, Cannon Hill, Brisbane, while the Council is supplying and maintaining the necessary research workers.—ED.

1. Introduction.

In making pH measurements by the use of the double quinhydrone electrode as suggested by Veibel, and elaborated by Biilmann and Torborg-Jensen, or indeed by any method employing platinum or gold ends sealed into glass, erroneous readings are liable to occur which may be due entirely to difficulties with the electrodes. The heating involved in the cleaning of the platinum or gold by the use of hot chromic acid cleaning solution, by boiling in 50 per cent. nitric acid, or by flaming, is sometimes responsible for considerable difficulty in respect to the cracking of the glass where the wire is sealed in. The development of these cracks usually renders the electrode unreliable or useless, and resealing is necessary. As a result of these cracks, one or more of the following may occur:—

(*a*) Mercury may reach the surface of the metal end and poison it.

(*b*) Mercury may find its way into the solution under test.

(*c*) Solution under test may get into the cracks in sufficient amount to contaminate the next sample being tested, thereby affecting the reading should this solution be unbuffered.

(*d*) The solution may migrate upwards into the glass tubing containing the mercury, where, under certain conditions, it may be responsible for spurious electrode potentials.

The difficulty with mercury has frequently been avoided by making a permanent sweated connexion of the potentiometer lead to the platinum of the electrode, before sealing. This procedure does not avoid all the difficulties involved in cleaning, however, nor a difficulty recently encountered when a special blue sealing-in glass was used. The unreliability of the electrodes so sealed was traced to the poisoning of the platinum surface, presumably by lead reduced from what was found to be a lead glass.

Some recent work in this laboratory necessitated especial care in the cleaning of electrodes. The troubles resulting from such cleaning procedure in respect to the frequent cracking of all samples of glass locally

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available were so persistent that attention was given to the elaboration of a glass-free electrode having none of the disadvantages mentioned above.

2. The Improved Electrode.

Twenty cm. of 3 mm. (approx.) "Tobin" bronze welding rod was covered with a sheath of insulating "Empire" cotton tubing, commonly known in the electrical trade as "spaghetti." This tubing was slipped on over the bronze rod which had been coated just previously with shellac, and the whole allowed to dry thoroughly. Some 5 mm. of the insulating tubing was then cut away at each end, the exposed metal ends cleaned, and the metal parts of two porcelain connectors fitted to them. The connecting wire to the potentiometer was screwed in at one end and the electrode end at the other. The electrode ends were made of fine platinum, approximately 1 cm. square and 0.25 mm. thick, to which was welded platinum wire approximately 5 cm. long and 1 mm. in diameter. Some were made with the wire normal to the platinum end and others with the wire and the end in approximately the same plane. The assembled electrode is shown in the accompanying photograph. (Fig. 1.)

After use, the loosening of a screw allows the removal of the whole of the platinum for such cleaning as is desirable. A few seconds suffice to replace the platinum in the holder. The length of the platinum wire (5 cm.) is sufficient to allow complete immersion of the metal end of the electrode with no risk of the solution under test wetting the connector.

Readings of the pH of carefully prepared standard buffer solutions, made with the type of electrode just described, have always been found to be quite accurate. The facility of assembling and dissembling, the ease of cleaning the platinum, the elimination of any risk of poisoning the platinum by other metals, the great saving in time, and the certainty of efficient operation are outstanding points in favour of this type of electrode, and are of great importance where any appreciable number of estimations of pH are being carried out.

It is quite possible that other workers have devised a similar electrode, but no reference to such has been noted in the literature.

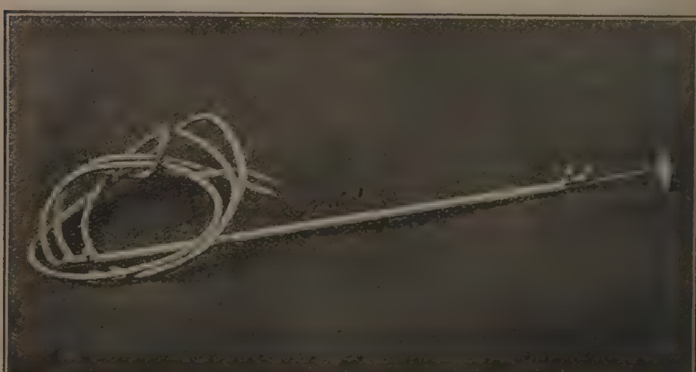

Fig. 1.—Photograph of the Improved Electrode.

Preliminary Experiments in Tasmania on the Relation of Internal Cork of Apples and Cork of Pears to Boron Deficiency.*

By W. M. Carne† *and D. Martin, B.Sc.*†

1. Introduction.

Internal cork of apples was first recorded in Australia by Cobb (6) as an obscure disease in Pomme de Neige (Fameuse). It was considered by McAlpine (7) to be a form of his confluent bitter-pit (crinkle). Mix (11) in the United States of America gave it the name of "cork" and "drought spot," according to the differences in the symptoms, and described an associated "die-back" of the shoot growth. Brooks and Fisher (4) in the United States of America, and especially McLarty (8, 9, 10) in Canada, recognised its possible association with soil and root conditions, particularly in relation to the water balance of the tree. The latter described as "corky core" a form of the trouble affecting only the core. Rigg and Tiller (12) recorded the disorder in New Zealand and noted its association with soil and soil moisture, but observed that chronic drought conditions were insufficient to account for its occurrence.

Carne and his colleagues (5) in Australia adopted the name "internal cork." This was used by Thomas and Raphael (15) in describing a trouble in Sturmer fruits in Tasmania and an associated malformation of wood growth. Increasing attention to the disorder in New Zealand, where the name "corky pit" had become adopted, led to a finding by Atkinson (3) that a liquid injection of boron, using the method of Roach (13), reduced the disorder in affected trees. Askew (1, 2) in New Zealand obtained results indicating that boron deficiency might be the primary cause. He concluded that low moisture content of soil and fruit was not correlated with the trouble, but that "low moisture supply in any soil subject to the condition might accentuate the trouble." McLarty, in a private communication of November, 1935, stated that "drought spot" and "corky core" had been controlled in his experiments in Canada by the injection of boron salts into the trees.

By the exchange of specimens with New Zealand, it was determined that the trouble there was symptomatically the same in the same varieties in Tasmania. There is no doubt that the same disorder has been variously known as "internal cork" and "corky core" together with some forms known as "cork" and "drought spot" in various parts

* These investigations were started in 1935 by W. M. Carne and D. Martin. Owing to the absence of the former in England from January, 1936, the latter has been responsible for the results obtained. The investigations are still in progress.

† Officers of the Division of Plant Industry, C.S.I.R., accommodated at the University of Tasmania, Hobart.

of North America, New Zealand, and Australia. Roughly the synonymy is as follows :—

Internal Lesions.—Internal cork in Australia.
Corky pit in New Zealand.
Cork of Mix (11) in U.S.A.

Superficial Lesions.—Drought spot of Mix, Brooks and Fisher in U.S.A. and McLarty in Canada.

These names relate to the fruit disorders occurring typically in Pomme de Neige, Sturmer, and Granny Smith. "Corky core" is a specialized form of internal cork affecting only the core and occurring typically in Jonathan. Typical drought spot has not been recorded in Australia.

Die Back.

This term has been applied to troubles of different origin, and is not necessarily, or even generally, to be attributed to the cause resulting in internal cork. The reduction of growth and failure of leading stems to maintain their upward growth, malformed shortened shoots, and even the death of shoots, have been associated, under the name "die back," with internal cork, and probably are at least in part due to the same cause.

Incidence of Internal Cork.

In Tasmania, the disorder has been noted in the following varieties of apples :—

Susceptible.—Sturmer and Granny Smith. These frequently show malformation of the fruit.

Pomme de Neige, Duke of Clarence and Jonathan. Malformation of the fruit less usual. In Jonathan the normal form is corky core.

Less Susceptible.—French Crab, Delicious, and Dunns, Cleopatra. (Placed here because of malformation or dimpling of the fruit suggesting internal cork, but without internal lesions. The trouble may be distinct from internal cork. See conclusions.)

Nearly or Quite Resistant.—Crofton and Democrat.

A cork of pears which symptomatically suggests internal cork of apple has been noted in Australia as shown below. Except for the similarity of symptoms, there has been no evidence that the apple and pear disorders have a common origin, though the two were both included by McAlpine as forms of his confluent pit (see conclusions). Varieties recorded as affected are as follows :—

Tasmania—
B. Bosc.
B. Clairgeau
B. Capiaumont.
G. Morceau.
W. Nelis.
W. Cole.
Josephine.
Gansells' Bergamot.

Other Australian States—
B. Bosc, Western Australia.
B. Clairgeau, South Australia.
W. Nelis, Victoria.
Josephine, Western Australia and Victoria.
W. Bartlett, Western Australia and South Australia.
Broom Park, Victoria.
Golden Beurre, Victoria.

Description of Internal Cork. (See also Mix (11) and Rigg and Tiller.)

The lesions commence as clear or slightly greenish injected areas in the flesh, usually not exceeding 1 cm. diameter, of rounded definite outline, and ranging in position from within the core line to just beneath the skin. In the latter case they may be visible through the skin and may be accompanied by a clear exudate on the surface. The injected spots dry out and turn dark from the centre, finally forming dark-brown spongy lesions with, especially in Sturmer and Granny Smith, a characteristically greenish margin. In other varieties the margin is less characteristic and persistent.

The lesions have been noted as early as November in Sturmer and Granny Smith when the fruit was about 2 cm. in diameter. They may continue to form during the life of the fruit, but at what stage during its life lesions cease to be initiated is uncertain. Observations would appear to indicate that they form later in Pomme de Neige, Duke of Clarence, and Dunn's than in Sturmer and Granny Smith. The disorder in Cleopatra which resembles internal cork in the external malformation of the fruit, but differs in having no internal lesions, also appears to occur early in the life of the apple. If the lesions are initiated when the apple is small, subsequent growth results in the malformation or dimpling of the surface.

Lesions vary in size and are usually under 1 cm. in diameter, but may be confluent. They may occur in the core only, the cortex only, or in both. In the core the lesions may be so confluent as to involve the whole core, or, in the corky core form, the whole core may be involved without evidence of separate lesions. In the former type the lesions may dry out and form cavities, but this has not been noted in corky core.

Internal cork may be associated with both strongly and weakly growing trees, but a form of stunted thickened growth, sometimes accompanied by vascular abnormalities, may be associated with the fruit trouble, and it is not uncommon to find affected trees or branches ceasing to make normal growth.

In the Huon district of Tasmania, internal cork occurs mainly on the Huon Sand, Grove Sand, and Lucaston Sand (14) soil types, but may be found on all the types in the area except the alluvial soils, especially when the surface soil has been more or less denuded.

2. Experiments in Tasmania.

Following information supplied by the New Zealand Department of Scientific and Industrial Research concerning results obtained in the control of cork by boron in apples during the 1934-35 season, preliminary tests were made to determine whether any control could be obtained with blotchy cork of apples and cork of pears. Three methods were used:—

(i.) Soil dressings of 3 lb. of boric acid per tree applied in midwinter over an area covered by the spread of the branches.

(ii.) Liquid injection, by the method of Roach (13), of a 0.25 per cent. solution of boric acid when the leaves had expanded in spring.

(iii.) Solid insertion of 0.5 gm. and 1 gm. boric acid in September in holes and in trunk or branches.

The trees selected were known to be affected in the previous season and usually for some seasons prior to that. In general, the occurrence of internal cork was not as severe in 1935-36 as in the season of 1934-35.

3. Internal Cork of Apples.

(*a*) *Soil Dressings.*—

Experiment 1.—

Soil Type.—Lucaston Sand.

Material.—14 Granny Smith bearing grafts which had been affected for at least three previous years on Sturmer trees which had been reworked because of their liability to internal cork.

6th May, 1935.—8 trees treated.

28th October, 1935.—Some boron injury evident as a bronzing of the leaves developing into brown spots and areas on the leaf edge and between the amin lateral veins.

8th November, 1935.—Trees apparently recovering except one very small weak tree.

30th March, 1936.—Treated trees free from internal cork. Sturmer fruits on the stocks and Granny Smith on the scions of the untreated trees affected with internal cork.

Experiment 2.—

Soil Type.—A denuded yellow clay outside soil surveyed area and not classified.

Material.—16 Sturmer trees affected for at least three previous years.

21st June, 1935.—8 trees affected.

30th October, 1935.—No definite leaf injury apparent.

15th April, 1936.—Treated trees free from internal cork. Of the controls, 5 affected, 3 not affected. Heavy rains fell after the soil dressing and before the ground was hoed, and it is probable that some boron was washed from the treated trees into the soil occupied by the three free control trees.

(*b*) *Liquid Injections.*—

Experiment 1.—

Soil Type.—Lucaston Sand.

Material.—15 Sturmers affected 1933-35.

27th October, 1935.—5 trees treated, 2,000 ml. 0.25 per cent. boric acid solution per tree.

9th April, 1936.—Treated trees free, controls 1 free, 9 affected.

Experiment 2.—

Soil Type.—Huon Silty Loam.

Material.—15 Sturmer trees.

27th October, 1935.—3 treated as above, 2 treated with 1.500 ml. solution.

9th April, 1936. -Treated trees free, controls 7 free 3 affected.

Experiment 3.—

Soil Type.—Unknown.

Material.—5 Sturmer trees, 1 Delicious.

20th October, 1935.—2 Sturmer trees treated and 1 Delicious all with 1,500 ml.

9th April, 1936.—Treated trees free, controls all three affected.

Experiment 4.—

Soil Type.—Lucaston Sand.

Material.—2 Sturmer and 2 Granny Smith.

29th October, 1935.—1 Sturmer treated with 1,750 ml. and 1 Granny Smith with 1,500 ml.

April 9th, 1936.—Treated trees free, controls affected.

Experiment 5.—

Soil Type.—Huon Sand.

Material.—5 Sturmers.

20th October, 1935.—3 treated with 2,000 ml.

9th April, 1936.—Treated trees free, controls affected.

(*c*) *Solid Insertions.*—

A ½-inch auger hole was bored nearly through one of the main branches, or, if the tree was small, into the main trunk, and 1 gm. or 0.5 gm. boric acid inserted, either loose or in a gelatine capsule, and the hole then closed with a cork and sealed with vaseline. Whenever possible, an attempt was made to treat a portion of the tree only, leaving the remainder of the tree as a control. The results showed that this method was effective, as there was little evidence of lateral spread or basipetal movement of the salt. In most cases, side branches on the treated limbs were apparently not affected by the treatment and accounted for the percentage of affected fruit when it occurred on the treated limbs. The following table shows the results obtained from solid insertions with Sturmers. For a typical effect see Fig. 1.

Plot.	Soil Type.	Pairs of Treated and Untreated Limbs.	Percentage Internal Cork on Treated Limbs.	Percentage Internal Cork on Control Limbs.	Difference.	t.	P.	Significance.
			%	%				
1	Grove Sand	9	11·2	38·7	27·5	3·47	< ·01	+++
2	Grove Sand	9	1·0	5·0	4·0	2·90	< ·02	++
3	Huon Sand	9	0·5	46·0	45·5	4·50	< ·01	+++
4	Huon Sandy Loam	8	Nil	25·0	25·0	3·80	< ·01	+++

(*d*) *The Effect of Time of Application of Solid Insertions.*—

Of 21 trees (Sturmer) on Huon Sandy Loam and affected in previous years, 14 were treated in the main trunk, one with 0.5 gm. boric acid loose, and one with 0.5 gm. in a capsule each week from the 2nd of September to the 14th of October. All the treated trees remained free from internal cork. Of the 7 non-treated trees, 3 were affected with internal cork.

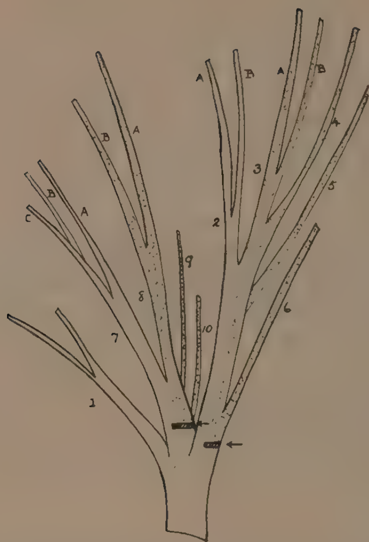

FIG. 1.—Diagram of a tree showing the effect of treatment with boric acid. (Method of inserting powder.)

Two limbs injected with 0.5 gm. boric acid at points shown by arrows on 23rd September, 1935. Tree 100 per cent. affected with cork in 1934-35.

Percentage of Internal Cork on 8th April, 1936:—Limb 1, 55; branch 2A, 55; Branch 2B, 60; Branch 3A, 0; Branch 3B, 0; Branch 4A, 6; Branch 5A, 0; Branch 6A, 0; Branch 7A, 39; Branch 7B, 59; Branch 7C, 14; Branch 8A, 0; Branch 8B, 0; Branch 9A, 0; Branch 10A, 0.

Stippled portion shows probable course of the boron salt.

(e) *Effect of Solid Insertions on Miscellaneous Varieties.*—

Soil Type.—Huon Sandy Loam.

Material.—One large Pomme de Neige tree with 3 main branches, affected for a number of years previously.

September, 1935.—Branch 1 left as control; branch 2 received 1 gm. boric acid loose; branch 3 received 1gm. in capsule.

March, 1936.—Branch 1 showed 100 per cent. affected fruit; branch 2 showed 100 per cent. sound fruit; branch 3 showed 50 per cent. affected fruit.

Soil Type.—Huon Sand.

Material.—Eight Duke of Clarence trees previously affected for some years.

September, 1935.—Three trees treated with 1 gm. boric acid loose; 2 trees treated with 1 gm. boric acid in capsule.

January, 1936.—Treated and control trees were free from internal cork.

(*f*) *Storage Experiments with Fruit from Treated and Untreated Apple Trees.*—

The fruit from the treated trees and controls was stored for 20 weeks at 34°F., and then for three weeks at room temperature, 55°F. The results are summarised below on the basis of significance.

Plot.	Trees Treated.	Control Trees.	Internal Cork.	Pit in Store.	Breakdown in Store.
1	11	11	++	++	Nil
2	4	7	++	−+	++
3	4	8	++	Nil	+−
4	4	4	++	+−	+−

Where ++ difference in favour of treatment significant.
Where +− difference in favour of treatment not significant.
Where −+ difference in favour of no treatment significant.
Where −− difference in favour of no treatment not significant.

The results indicate that internal cork was consistently and significantly reduced by boric acid treatments. There seemed also to be some effect on pit and breakdown in cool store, but the results were not consistent.

4. Internal Cork (?) or Dimple of Cleopatra.

Liquid Injection.—

Soil Type.—Unknown.

Material.—Cleopatra tree affected for many years. 1931, cut back and regrafted with Cleopatra scions from a reputedly unaffected tree. Bore affected fruit on scions in 1934-35 season.

October, 1935.—Injected 1,500 ml. 0.25 per cent. solution boric acid.

January, 1936.—All fruit affected.

Cork of Pears.—

Liquid Injection.—

Plot 1.—Soil Type.—Huon Sand.

Material.—Giblin's Seedling, affected 100 per cent. for many years.

October, 1935.—Injected with 2,000 ml. 0.25 per cent. solution boric acid.

March, 1936.—Fruit still 100 per cent. affected.

Plot 2.—Soil Type.—Lucaston Sand

Material.—B. Bosc, 50 per cent. affected 1934-35.

October, 1935.—Injected with 2,000 ml. 0.25 per cent. solution.

March.—No fruit affected.

Plot 3.—Soil Type.—Lucaston Sand.

Material.—B. Capuamont, affected 100 per cent. for many years.

October, 1935.—Injected with 1,500 ml. 0.25 per cent. solution.

March, 1936.—Still 100 per cent. affected.

5. Blotchy Cork.

(*a*) *Liquid Injection.*—

Soil Type.—Mixed.

Material.—Cleopatra, 2 rows of 12 trees, each affected every year with blotchy cork and previously used for pruning experiments for its control. Each row had received the same treatments (4 treatments of 3 trees each.)

1st November, 1935.—One row of 12 trees each treated with 2,000 ml. 0.25 per cent. solution.

14th November, 1935.—One row of 12 trees, each treated with 2,000 ml. 0.25 per cent. solution.

March, 1936.—All fruit from the 24 trees picked, blotchy cork removed and sized. All fruit badly affected with black spot also removed and counted. The remainder was stored for ten weeks at 38°F., then sized and examined, and after three weeks at room temperature, 55°F.—cut and examined for bitter pit. The results were examined by the method of "Student," comparing the treated and untreated trees in pairs. The results were as under:—

—	Percentage of Blotchy Cork on Tree.	Percentage of Pit in Store.	Diameter in Inches.
Untreated—treated	9·3	13·2	0·085
t	2·38	1·8	4·7
P	0·04	0·1	·01
Significance	—	—	+++

The correlation coefficient for size and percentage blotchy cork in the 24 trees r = 0.064, which is not significant.

(*b*) *Solid Treatment.*

Plot 1.—Soil Type.—Mixed.

Material.—Group of Sturmer trees usually ± affected with blotchy cork.

September, 1935.—Three trees treated with 1 gm. loose boric acid; 2 trees treated with 0.5 gm. loose boric acid; 2 trees treated with 1 gm. boric acid in capsules; 3 trees treated with 0.5 gm. boric acid in capsules. Controls, 14 trees.

April, 1936.—Blotchy cork absent on both treated and control trees.

Material.—Group of Cleopatra trees always ± affected with blotchy cork.

September, 1935.—Two trees treated with 1 gm. loose boric acid; 2 trees treated with 0.5 gm. loose boric acid; 4 trees treated with 1 gm. boric acid in capsules; 2 trees treated with 0.5 gm. boric acid in capsules. Controls, 7 trees.

April, 1936.—No obvious difference in amount of cork on treated and untreated trees.

Material.—Group of Democrat trees usually ± affected with blotchy cork (?).

September, 1935.—One tree treated with 0.5 gm. loose boric acid; 1 tree treated with 0.5 gm. boric acid in capsule. Controls 4 trees.

April, 1936.—Cork absent from both treated and control trees.

Plot 2.—Soil Type.—Huon Sandy Loam.

Material.—Group of Sturmer trees usually ± affected.

September, 1935.—One tree treated with 0.5 gm. loose boric acid; 1 tree treated with 0.5 gm. boric acid in capsules. Controls, 2 trees.

April, 1936.—Cork absent from both treated and control trees.

Plot 3.—Soil Type.—Huon Loam.

Material.—Four Sturmer trees.

September, 1935.—One tree treated with 0.5 gm. loose boric acid; 1 tree treated with 0.5 gm. boric acid in capsules. Controls 2 trees.

April, 1936.—Cork absent from both treated and control trees.
Soil Type.—Huon Loam.
Material.—Eight Cleopatra trees.

September, 1935.—Two trees treated with 1 gm. loose boric acid; 2 trees treated with 1 gm. in capsules. Controls 4 trees.

April, 1936.—No obvious difference between treated and untreated trees.

6. Conclusions.

1. Soil dressings of 3 lbs. of boric acid per tree were completely effective in controlling internal cork, but on light soils and small trees caused some injury.

2. Liquid injections of 1-2 litres of 0.25 per cent. solution of boric acid were completely effective with slight leaf injury in the branches immediately above the injection. Injections have been effective in all parts of the tree when injected only into one fork of the trunk.

3. Solid insertions appear to affect only those branches in immediate connection with the hole.

4. On the limited evidence available, it would appear that the dimpled condition in Cleopatra and cork in pears were not affected by the treatment in 1935-36. This is in line with other evidence which suggests that the causes of these troubles may be different from those causing internal cork in apples.

5. Blotchy cork in Cleopatra apparently responded to liquid injection. It is doubtful whether the result is of significance in view of the highly significant difference in the size of the fruit.

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Studies on the Heat Sterilization of Beef-Wrapping Materials.

*By W. A. Empey, B.V.Sc.**

The work described in the article that follows forms part of the programme which is being carried out by the Council's Section of Food Preservation and Transport in co-operation with the Queensland Meat Industry Board. The lines of that co-operation and some details regarding the programme itself, have been given in a previous issue (this *Journal* 5: 133, 1932). Briefly, the Meat Industry Board has provided the buildings and equipment for the Section's laboratory at the Brisbane Abattoir, Cannon Hill, Brisbane, while the Council is supplying and maintaining the necessary research workers.—Ed.

Summary.

1. Beef-wrapping materials (hessian and stockinette) normally contain micro-organisms which are viable on suitable media at —1°C.
2. A method has been developed for the measurement of the resistance to elevated temperatures of the spores of four different moulds capable of growth on chilled beef tissues at —1°C.
3. The temperature-time relationships necessary to kill viable spores of these moulds in the beef wraps have been determined under commercial conditions.

1. Introduction.

In order to provide some degree of protection for beef which is to be shipped in the chilled condition, the quarters are wrapped in coverings of stockinette, a cellular cotton fabric, or hessian, a cellular jute fabric. Generally, two coverings are used for each quarter, an inner one of stockinette and an outer one of hessian. Microbial examinations of these coverings have shown them to possess varying numbers of micro-organisms, some of which are capable of growth at —1°C. (30.2°F.) (the approximate temperature for the storage of chilled beef). Because of the fairly close contact between these coverings and the surface of the quarters, it is possible that some of these organisms may be transferred to the beef. If provided with a suitable environment for their proliferation, these organisms will, in varying degrees, supplement the microbial populations existing on the quarters at the completion of storage. In order to exclude such sources of contamination, it is necessary to adopt methods for the elimination of the "low temperature type" organisms from the coverings before they are applied to the quarters. Various methods have been suggested for this purpose, but the one which has the fewest objections from the commercial aspect is that of disinfection by dry heat.

In practice, it is frequently necessary simultaneously to treat several tons of wraps. These are usually distributed in loose bundles of varying thicknesses throughout rooms which are heated either by means of grids of steam pipes or by electric elements. The temperature at which the air is maintained in the room is governed chiefly by risks due to the possible ignition of either timber or wrapping materials in close

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proximity to the source of heat, and also by the danger of the production of unpleasant odours in hessian subjected to excessively high temperatures. In practice, the air temperature is not allowed to exceed 88°C. (190°F.). The following investigations have been undertaken with the object of determining the conditions necessary to ensure the elimination of the "low temperature type" micro-organisms on wraps subjected to such a process of disinfection.

2. Experimental.

(i) *Nature and Extent of Microbial Contamination.*

The nature and extent of the microbial contamination occurring on the wraps were determined by estimating the numbers of viable organisms per unit area. Composite samples taken from various sources were well shaken in physiological saline (0.9 per cent. sodium chloride) with sterile sand. Suitable dilutions were then plated out in nutrient beef-extract peptone agar, pH 7.2. The poured plates were incubated both at 20°C. (68°F.) and at −1°C. (30.2°F.), and counts were made after incubation for eight days at the former temperature and after 20, 30, and 40 days at the latter. The results of four separate experiments are shown in the following table:—

TABLE 1.—MICROBIAL CONTAMINATION OF WRAPS.

Material.	Populations per Square Cm. of Material.							
	Incubated at 20° C.		Incubated at − 1° C.					
			At 20 Days.		At 30 Days.		At 40 Days.	
	Bacteria.	Moulds.	Bacteria.	Moulds.	Bacteria.	Moulds.	Bacteria.	Moulds.
Hessian ..	30,000	40	0	0	1	0	1	< 1
Stockinette ..	6,300	6	0	0	2	0	4	< 1
Hessian ..	41,000	45	7	0	13	0	20	1
Stockinette ..	43,000	38	1	0	3	0	35	2
Hessian ..	28,000	400	4	0	14	0	16	1
Stockinette ..	2,500	100	2	0	2	0	4	1
Hessian ..	15,000	800	0	0	2	0	5	3
Stockinette ..	1,000	100	0	0	7	0	16	< 1

Of the "low temperature type" organisms, the bacteria belonged to the genus *Achromobacter* (Bergey et al.), whilst the moulds comprised *Cladosporium herbarum*, *Sporotrichum carnis*, *Penicillium* spp., and *Mucor* spp. The numbers of such moulds per unit area are not unduly high, but, since chilled beef, at the conclusion of its preparation in the meatworks, usually has considerably less than one "low temperature type" mould spore per square centimetre of surface, such a source

of subsequent contamination may be relatively important. The bacteria, which greatly outnumber the moulds, would be transferred in correspondingly greater numbers, but, under normal conditions, the populations of these "low temperature types" usually exceed 20 per sq. cm. on beef prepared in the Queensland meatworks. It will be noted that some samples of wrapping materials contained fairly active strains of *Achromobacter,* as evidenced by the visibility of their colonies after incubation for 20 days at —1°C.

(ii) *Measurement of Resistance of "Low Temperature Type" Organisms to Elevated Temperatures.*

Achromobacteria.—Preliminary experiments indicated that the Achromobacteria were considerably more susceptible than the moulds to the influence of elevated temperatures. Death of these bacteria commenced at a much lower temperature level, and they were killed under conditions which had no lethal effect on the mould spores. The "critical" temperature for two pure strains of *Achromobacter* was about 40°C., and there were no survivors after an exposure for one hour at 50°C., whereas none of the mould spores were killed as the result of the latter treatment. It was thought advisable, therefore, to pay most attention to the moulds.

Moulds.—Since the numbers of "low temperature type" moulds were of such a low order and their distribution on the wrapping materials so uneven, it was more convenient to determine their resistance to elevated temperatures on artificially inoculated portions of the textiles. Preliminary experiments showed that their resistance was comparable on both types of wrapping material; on account of greater ease of handling, hessian was therefore used for experimental purposes. Suspensions of mould spores were prepared from artificial cultures grown on Czapek's agar at 20°C. for varying periods. Breaking up the clumps of spores was effected by grinding with sterile sand and water, followed by vigorous shaking with subsequent filtration through sterile cotton wool pads. Strips of hessian, previously sterilized by dry heat, were immersed in the suspensions, and after saturation they were allowed to drain in order to remove the excess fluid. They were then partially dried on sterile pads of filter paper, and finally dried at ordinary room temperatures (20° to 30°C.) for periods of from three to sixteen hours. Portions of the dried material were chosen at random, both for exposure to elevated temperature and for holding as controls at 20°C. for the duration of the experiment. The units chosen were approximately 50 sq. cm. in area and were equivalent to at least 20 per cent. of the total area used in each individual experiment. Heating was carried out in stoppered, thin-walled, sterile, glass tubes held in a thermostatically controlled bath holding circulating water at a temperature within ±0.01°C. of the desired level. The tubes were preheated to the temperature of the bath prior to the introduction of the samples,, and, under these conditions, the lag period before the material farthest away from the walls of the tube rose to the temperature of the bath did not exceed ten minutes. Counts were carried out by the method previously described, except that the survival test medium was Czapek's agar of pH 6.3. In most experiments, incubation was carried out at 20°C., but in some, additional counts were done at —1°C. It had previously been shown that comparable numbers of unheated spores

were viable at both temperatures in the case of the individual strains of "low temperature type" moulds used, namely, *Sporotrichum carnis*, *Cladosporium herbarum*, *Penicillium* sp., and *Mucor* sp. The heated samples were allowed to cool to the temperature of the diluting saline prior to their immersion therein. In all instances, there were no measurable changes in the numbers of viable mould spores in the control samples held at 20°C. for periods up to 48 hours. Preliminary trials showed that, under the conditions of these experiments, death of moulds commenced at about 52°C. (125.6°F.). The death rate for mould spores at this temperature was of a low order, and the majority of trials were therefore carried out between 55°C. (131°F.) and 65°C. (149°F.). The results of these are shown in Table 2, in which the percentage "kills" are based on the numbers of survivors viable at 20°C. and capable of producing visible colonies within eight days at this temperature.

TABLE 2.—EFFECT OF ELEVATED TEMPERATURES ON MOULD SPORES SUSPENDED IN DRY HESSIAN.

Temperature Degrees C.	Mould.	Population per Square Cm. (viable at 20° C.).	Percentage "Kill." Duration of Exposure (Hours). 0·5.	1.	2.	3.	4.	6.	19.
55·0 ..	*Penicillium* ..	12,000	..	..	..	..	45	..	77
60·3 ..	*Mucor* ..	1,240	..	50	..	70	..	..	..
	Penicillium ..	8,400	..	30	..	91	..	..	..
	Sporotrichum	15,000	..	60	..	97	..	..	..
60·3 ..	*Mucor* ..	200	..	..	30	..	55	..	..
	Penicillium ..	2,300	..	..	83	..	93	..	..
60·3 ..	*Mucor* ..	30	..	..	67	..	..	87	..
	Penicillium ..	350	..	..	66	..	..	92	..
	Sporotrichum	1,800	..	..	85	..	..	96	..
65·0 ..	*Mucor* ..	100	..	98	..	99	..	99·6	..
	Penicillium ..	3,000	..	99·3	..	99·5	..	100	..
	Sporotrichum	23,000	..	98	..	100	..	..	..
65·0 ..	*Mucor* ..	100	95	97	..	99	..	..	..
	Penicillium ..	7,000	99·4	99·4	..	99·7	..	..	..
	Sporotrichum	44,000	91	98·5	..	100	..	..	..
	Cladosporium	6,000	..	100	..	..	..	..	..

This table shows that it was necessary to maintain the material at 65°C. for a period of one hour in order to approximate a complete kill for each of the four moulds. No marked differences in susceptibility

to elevated temperatures could be detected. It was noticed, however, that the development of visible colonies from the surviving spores was delayed by two to three days at 20°C., depending on the temperature applied. While in certain instances also, some of the surviving spores subsequently germinated in the plating medium, after the production of comparatively small mycelia they showed no further development and did not produce visible colonies, even after prolonged incubation at 20°C. These fractions were not included amongst the survivors as shown in Table 2. With incubation at —1°C., further evidence of changes in the growth characteristics of the survivors was obtained. In one trial, the unheated spores of *Penicillium* just became visible at —1°C. in 33 days, the count equally in 37 days the numbers viable at 20°C. When a duplicate sample was heated at 60.3°C. (140.5°F.) for two hours, of the 34 per cent. survivors viable at 20°C. (see Table 2) the first visible colonies appeared in 66 days at —1°C., whilst those showing between 66 and 93 days reached one-third of the count at 20°C. After subsequent incubation for six days at 20°C., a further one-third appeared, but the remaining fraction failed to develop. In the case of the spores of *Mucor* heated under similar conditions and showing 33 per cent. of survivors viable at 20°C., there was no development by the survivors into visible colonies in 93 days at —1°C., or subsequent incubation of these plates at 20°C.

Confirmation of the adverse effect on the growth characteristics of the spores which survive varying periods of exposure to elevated temperatures has been obtained in other experiments. From the practical stand-point, therefore, it should not be necessary to obtain a complete kill of the heated mould spores in order to render them innocuous during the storage of chilled beef at —1°C. for periods up to 55 days, particularly when carbon dioxide is used in the storage environment. In order to be certain of this, however, experiments in which beef tissues are used as the survival test media should be carried out, and further species and strains of the "low temperature type" moulds should be tested.

(iii) *Tests on a Commercial Scale.*

In order to determine the efficiency of the heating rooms used in commercial practice for the disinfection of wraps, pieces of hessian, artificially inoculated with spores of *Penicillium* sp. and *Mucor* sp., were placed in the geometrical centres of stacks of hessian and stockinette of varying dimensions, and subjected to the normal process of heating. Temperatures at various points in the air throughout the room and also in the interior of the stacks in proximity to the inoculated samples were measured by means of distant-reading resistance thermometers. The temperature-time relationships for two such tests are shown in the accompanying graphs (Figs. 1 and 2). In both experiments, the inoculated samples were removed for counting at the completion of the total period of exposure of approximately 44 hours. In Experiment 1 (Works A), the conditions were such that none of the inoculated samples rose in temperature above the "critical" level, which, for practical purposes, may be taken as 52°C. (125.6°F.). The only noticeable effect was that, in those samples heated to about 48°C. (118.4°F.), there was an extension of the lag period at —1°C. of about five days for the spores of *Penicillium* and about seven days for

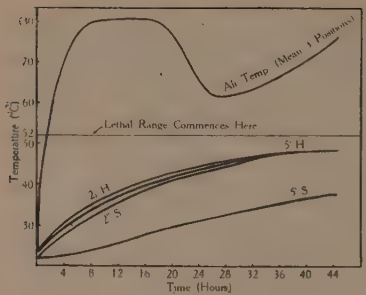

FIG. 1.—Temperature - time curves for the air, and for stacks of beef wraps of varying thicknesses in heating room at Works A.

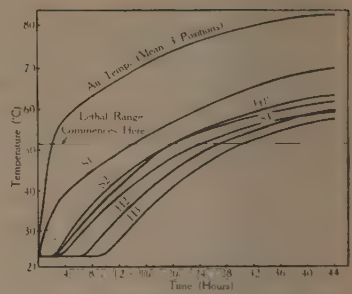

FIG. 2.—Temperature - time curves for the air, and for stacks of beef wraps of varying thicknesses in heating room at Works B.

those of *Mucor*. In Experiment 2 (Works B), all of the inoculated samples remained for sufficient time above the "critical" temperature to give a complete kill (see Table 3).

TABLE 3.—EFFECT OF ELEVATED TEMPERATURES ON THE SPORES OF *Penicillium* SP., AND *Mucor* SP., WHEN HEATED UNDER COMMERCIAL CONDITIONS.

Material.	Thickness (Feet).	Range of Lethal Temperatures Deg. C.	Time above "Critical" Temperature Hours.	"Kill" Percentage.
Stockinette	1	52–70	29	100
	2	52–62	24	100
	3	52–59.4	20	100
Hessian	1	52–62	24	100
	2	52–59	17	100
	3	52–58	13	100

The reasons for the superiority of the heating room at Works B over that of Works A were as follows:—

(*a*) The wraps occupied one-fifth of the total air space in B and one-half of the space in A.

(*b*) The volumes of the individual stacks were less in B than in A.

(*c*) Each stack in B was completely surrounded by a free air space, whereas the stacks in A were packed tightly. The stacks in B were arranged on a metal grating about 3 feet above floor level, whereas a large proportion of those in A were placed directly on the floor.

(*d*) The air temperatures in B were uniform both in time and space.

3. Discussion.

While it has been demonstrated that exposure for one hour at 65°C. (149°F.) is necessary in order to effect an approximately complete "kill" of the spores of the four different "low temperature type" moulds which were artificially inoculated on hessian wrapping material, it has also been shown that the inhibiting effect of exposure to somewhat lower temperatures, on the subsequent growth characteristics of the survivors, may be sufficient to render them comparatively innocuous at —1°C. The temperature-time relationships necessary to ensure sufficient restriction in the development of the surviving spores when transferred to chilled beef stored for about 55 days in 10 per cent. carbon dioxide at —1°C. have not been accurately determined, but it would appear that an exposure of the wraps for two hours at about 60°C. (140°F.) should provide an adequate margin of safety. This well-defined condition cannot be set as a standard for commercial practice on account of the very gradual rise of temperature in the bulk of the wraps, and, consequently, a minimum period at temperatures above the "critical" level of 52°C. (125.6°F.) must be chosen. In experiments on a commercial scale, a period of thirteen hours within the lethal range of 52°–58°C. has been shown to effect a practically complete sterilization. The more susceptible Achromobacteria (which were unable to survive an exposure of one hour at 50°C.) would be killed in considerably less time, under these conditions, than the spores of the moulds.

Because of the variations which exist between different heating rooms, it is not possible to outline rigid standards in regard to the maximum allowable weight of wrapping materials, the optimum size and disposition of the stacks, and the minimum period for the maintenance of the air temperature at about 88°C. (190°F.), in order that each wrap should rise in temperature above the "critical" level for a sufficient period. For rooms in which the air temperature is maintained at about 88°C. for approximately 44 hours, sterilization of the wraps should be satisfactory if the volume of each individual stack does not exceed 15 cubic feet, and if a free air space completely surrounds each stack. Generally, however, an accurate temperature survey of each loaded heating room will be necessary in order to determine whether conditions conducive to adequate sterilization are being maintained.

The Influence of Tipping, Topping, Cincturing, and Disbudding on Growth and Yield in the Sultana Vine.

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Summary.

Experimental work dealing with certain summer treatments of the sultana vine, viz., tipping, topping, disbudding, and cincturing, has been carried out using mature vines on their own root system. The conclusions are:—

(1) The reaction of the sultana to tipping and topping depends upon the severity of the treatment and the vigour of the vine, but all forms of summer pruning are distinctly detrimental to weak vines and undesirable even for the most vigorous vines.

(2) Cane cincturing, either at setting time or later in the season, though causing an increase in yield during the first season of treatment, leads to a decline in production and vigour during subsequent seasons.

(3) Disbudding, if practised early in the season, does not appreciably influence either growth or yield. If carried out late in the season (November), it is equivalent to partial defoliation and results in a reduction of yield.

1. Introduction.

Several types of summer pruning, viz., tipping, topping, disbudding, and cincturing, are practised by the vigneron, and each treatment is of definite value under certain conditions. Tipping, topping, and disbudding are used with advantage in training young vines, while cincturing has very desirable effects on mature vines of some varieties. Very little is known regarding the effect of these treatments on mature vines of the sultana variety. All four treatments have, however, been applied to mature sultana vines by growers in the Mildura district, and considerable difference of opinion exists as to the benefits obtained. Experimental work dealing with the reactions of these vines to the treatments was therefore undertaken, and the present article contains an account of these studies.

Tipping or "pinching" means removing the tips of the growing shoots; topping involves cutting off portion of the distal end of the shoots as well. Summer pruning of this type has been practised on mature vines and strongly advocated by a number of growers in the Mildura district since about 1912, it being maintained that fruit-bud formation and consequently yields in the following season are greatly increased. Anthony‡ working in the State of New York, United States of America, found that pinching the shoots of vinifera grape vines when about 30 inches long resulted in more mature canes for the following season and "if properly done added to the fruitfulness of the vine." Bioletti and Flossfeder§, on the other hand, found in California that while tipping and topping slightly increased the yield of fruit in the varieties Carignane and Tokay during the first season of treatment,

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‡ New York (Geneva) Exp. Stat., Bull. 432, p. 90, 1917.

§ Californian Agr. Exp. Stat., Bull 296, 1918.

they decreased the crop of the second season. The increase was attributed mainly to a better setting of the berries and to the fact that a small second crop was produced on the laterals which arose as a result of tipping. No increase in fruit-bud formation was reported. In view of these conclusions and the increasing popularity of the practice in the Mildura area, the desirability of investigating the effect of the operation on the yield and fertility of the sultana was apparent.

Cincturing, ringing, or girdling is an operation in which a narrow ring of bark is removed—usually from the trunk of the vine. Cincturing at flowering time is generally accepted as being most desirable in those varieties which produce seedless berries. It is necessary to prevent the abscission of flowers and berries at an early stage of development. Jacobs* has shown that in the Hunisa grape, a variety producing both fertilized (seeded) and unfertilized (seedless) berries, the only effect of girdling at flowering time is to increase the set of seedless berries. In the seedless Zante currant, cincturing has been adopted as a standard practice in the Mildura district and is indispensable in securing a satisfactory set. In the sultana, though the berries are seedless, setting is satisfactory under normal conditions without recourse to cincturing. As rudimentary seeds are present in the young berries, normal pollination and fertilization evidently occur and provide the requisite stimulus for setting. Seedlessness results from a subsequent abortion of the ovules. From time to time, cincturing has been practised on the sultana, however, and has been claimed to result in earlier maturity as well as increased berry set and bunch size. Lyon† has found that cincturing after flowering increases yield during the first season but results in a decrease during the following year. He therefore condemned the practice. The writers here report the results of girdling canes both at flowering time and during midsummer.

The operation of disbudding is slightly different for young and old vines. In young vines it consists in removing, during an early stage in development, all shoots not required in making the framework. In mature vines it consists in removing such barren or unfruitful shoots as could not be utilized for bearing wood the following season. In the sultana from 30 per cent. to 70 per cent. of the shoots are unfruitful, and disbudding is practised to a limited extent. It has been claimed that the barren shoots contribute but little to the development of the crop, and if removed early in the season allow the development of greater strength and vigour in the fruiting shoots. The operation has therefore been subjected to experimental trial.

During the course of preliminary experiments, data were obtained which suggested that the response to summer pruning of vines on their own root systems might be different from that of those on phylloxera-resistant stock. As commercial plantings of sultanas consist almost entirely of vines on their own roots, the present article, in order to avoid confusion, deals only with the results obtained from such vines.

2. Experimental Methods.

As uniformity trials in the Mildura district showed that a high coefficient of variability (i.e., in the order of 25-35 per cent. for yields of both fresh and dried fruit) may be expected in field trials with vines, the problem of plot technique became very important. It was hoped

* *Proc. Amer. Soc. Hort. Sci.* **32**: 387, 1934.

† Unpublished Report, Commonwealth Research Station, Merbein.

that experimental accuracy would be increased if a preliminary uniformity trial were performed on each block of vines, and the results applied in correcting the yields during the experimental year by means of the analysis of covariance*. In many perennial plants such as tea and rubber, the yields tend to be significantly correlated from year to year, and preliminary uniformity trials have been used to determine the constant of a regression equation from which the deviations of the experimental year have been corrected and the variance reduced. A series of uniformity trials, using single vine units, plots of 5 x 1 vines and Latin squares of 4 x 4 vines were carried out over several seasons. The analysis of covariance was applied to these data, and it was found that in so doing variance was diminished in some seasons but actually increased in others. Though under very favourable circumstances a nett gain in precision may have been obtained, the consideration that preliminary trials necessitated delaying each experiment for one year led to the abandonment of this procedure in subsequent experiments.

The single vine planted 11 feet x 9 feet was adopted as the unit of treatment and, except in the two experiments noted below, the trials were set out in the form of randomised blocks. Fisher's method of the analysis of variance was used to examine the results. In experiments 1 and 2, dealing with tipping, the vines were arranged systematically a b a b a b, &c., and Student's method was used in calculating the results when the data plotted in graph form gave no evidence of a fertility gradient.

Technical difficulties were also encountered in obtaining the yield of dried fruit for individual vines. The weight of fresh fruit may be easily measured, but, under the rack system of drying which is universally practised in the Mildura district, the separate drying of fruit from individual vines involves considerable labour. The necessity of obtaining such records was apparent, however, since it was found that certain of the treatments influenced the sugar content of the fresh fruit and hence, to a marked extent, the ratio of fresh to dry weight. In order to obviate the labour of separate drying, two methods were employed.

In one method samples were taken from the shoulder of at least 50 per cent. of the bunches on each vine just before harvest and composited; the juice was expressed and a specific gravity determination made by means of a hydrometer graduated in degrees Baumé. A drying ratio corresponding to this reading was employed to calculate dry weight.

In the second method the whole of the fruit from each treatment was bulked and rack-dried, the bulk drying ratio thus obtained being used to obtain the dry weight yields of the individual vines.

Justification for the use of the first method is provided in an examination of data obtained from an experimental field in March, 1936. Sixty-four vines, subject to two treatments set out in the form of randomized blocks, supplied records of the yield of both fresh and dried fruit and the Baumé of the juice of the fresh fruit. The individual dry weight yields were obtained by tray drying the fruit from individual vines separately. The correlation coefficient between Baumé and drying ratio was 0.92 and the corresponding regression equation for this year was D.R. = 10.63—0.555B, where D.R. equals the ratio of fresh fruit to dried weight (i.e., with 12 per cent. moisture content) and B equals degrees Baumé at 30°C. This correlation is considered sufficiently high to warrant the use of a calculated dry yield corresponding to the specific gravity of the fresh fruit.

* Sanders, H. S., *J. Agr. Sc.*, **20**: 63-73, 1930.

The above data may also be used to illustrate the criteria used in judging the significance of results obtained in the experimental work. The analysis of variance for the yields of fresh and dried fruit gave the results shown in Table 1.

TABLE 1.—ANALYSIS OF VARIANCE FOR YIELDS OF FRESH AND DRIED FRUIT.

Treatment.	Mean Yield of Fresh Fruit.	Mean Yield of Dried Fruit.
	lb.	lb.
(a)	38·2	8·88
(b)	47·6	11·21
	Z test negative	*Z* test positive

Although the percentage difference in mean yields of fresh fruit was greater than that in the mean yields of dried fruit, a positive result for the *Z* test was obtained for the latter only. In cases similar to this, where an analysis of the fresh fruit yields just failed to give a positive *Z* test but where the percentage difference in mean dry yields was greater, it was assumed, especially if associated with confirmatory data, that the difference was actually significant.

Other records, including the number of buds left after pruning, the weight of prunings, the number of buds which developed in spring and in some cases the total elongation growth of the shoots, were taken in addition to the yield of fresh and dried fruit.

3. Tipping and Topping Experiments.

(a) *Experimental.*

Tipping and topping trials were carried out on vines of different degrees of vegetative vigour, and in some experiments two different forms of tipping were employed. In other trials vines of comparable vegetative vigour were used, and the effects of tipping at different times were compared. The principal data obtained from these experiments are summarized in Table 2 and the results are discussed below:—

Experiment 1.—In Experiment 1, the vines were above average in yield and vigour. Two tippings were given to the shoots near the crown of the vine, the first in early November when the shoots were about 3 ft. 6 in. long and the second five weeks later. The purpose of the second treatment was to restrain the growth of the laterals which arose as a result of the first tipping.

The treatment did not appreciably affect yield during the first season but did increase fruit bud formation. The greater number of bunches produced by the tipped vines during the second season resulted in an increased yield of fresh fruit. The sugar content of this fruit, however, was lower than that of the controls, and there was no significant difference in the yields of dried fruit. During the third season no significant difference occurred in the number of bunches produced on

TABLE 2.—SUMMARY OF RESULTS* OF TIPPING EXPERIMENTS.

a = controls. b = shoots at crown of vine tipped. c = all shoots tipped.

Season.	Weight of Prunings.			Number of Buds.			Number of Shoots.			Number of Bunches.			Yield of Fresh Fruit in lb.			Specific Gravity of Juice. Degrees Baumé.			Yield of Dried Fruit in lb.		
	a	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*
										Experiment 1.†											
1931-32	..	..	..	..	..	..	..	..	..	..	..	..	28·5	29·8	..	..	..	..	..	..	..
1932-33	7·99	6·90	..	75·4	82·5	..	..	..	..	40·6	51·9 *b–a*	..	35·6	43·4 *b–a*	..	14·80	14·10 *a–b*	..	10·45	10·55	..
1933-34	7·87	5·95 *a–b*‡	..	100·4	105·3	..	53·5	56·5	..	33·3	36·1	..	30·2	31·5	..	14·42	14·04 *a–b*	..	11·45	11·07 *a–b*	..
1934-35	7·12	5·34 *a–b*	..	92·4	80·3 *a–b*	..	72·6	60·8 *a–b*	..	55·0	54·0	..	34·3	34·8	..	13·38	13·18 *a–b*	..	10·40	10·70	..
										Experiment 2.†											
1931-32	..	..	..	..	..	..	..	..	..	..	..	..	25·6	..	28·3	10·6	..	10·2	..	..	..
1932-33	7·20	..	6·80	..	..	..	..	..	..	48·7	.. *c–a*	55·8	40·7	.. *c–a*	50·5	13·20	.. *a–c*	12·50	12·40	.. *c–a*	13·80
1933-34	6·73	.. *a–c*	5·78	103·1	.. *a–c*	78·8	56·2	.. *a–c*	48·1	35·2	..	32·0	29·7	.. *a–c*	23·8	14·07	.. *a–c*	13·98	10·55	.. *a–c*	8·32
1934-35§	6·92	.. *a–c*	4·92	106·1	..	100·5	..	..	..	56·0	..	54·0	35·9	.. *a–c*	31·6	14·70	..	14·50	14·60	.. *a–c*	12·40
1935-36§	6·80	.. *a–c*	5·21	131·3	..	122·1	51·4	51·5	..	23·6	..	20·4	22·3	..	20·8	..	..	..	3·67	..	3·66

* Results given as means per vine.
† Number of replications = 57 in Experiments 1 and 2; 27 in Experiments 3 and 4.
‡ Where the difference between treatments is significant it is shown thus, *a–b*.
§ Treatments not applied in Experiment 2 during 1934–35 and 1935–36.

TABLE 2.—SUMMARY OF RESULTS* OF TIPPING EXPERIMENT—*continued.*

a = controls. *b* = shoots at crown of vine tipped. *c* = all shoots tipped.

Season.	Weight of Prunings.			Number of Buds.			Number of Shoots.			Number of Bunches.			Yield of Fresh Fruit in lb.			Specific Gravity of Juice. Degrees Baumé.			Yield of Dried Fruit in lb.		
	a	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*
										Experiment 3.†											
1932–33	..	..	..	..	..	..	..	..	..	..	..	..	54·4	61·9	60·6	11·83	11·50	11·86	13·48	14·60	15·60
														b–a						*c–a*	
1933–34	8·96	8·83	8·18	..	..	..	74·3	77·7	78·5	41·9	48·0	41·6	45·6	52·2	48·8	..	..	..	..	..	..
								b–a			*b–c*			*b–a*							
1934–35	8·60	7·50	7·70	..	..	..	79·8	86·8	84·2	51·3	57·6	51·0	..	..	..	..	..	..	..	..	..
		a–b, a–c						*b–a*													
1935–36	10·3	9·85	9·04	141·5	142·6	131·2	67·9	69·7	65·9	31·0	31·8	28·4	51·6	58·0	47·0	..	..	..	13·20	13·18	11·15
		a–b, a–c												*b–c*						*a–c, b–c*	
										Experiment 4.†											
1932–33	..	..	..	..	..	..	..	..	..	..	..	..	48·1	48·8	48·3	11·20	..	11·10	..	..	..
1933–34	3·70	3·50	3·40	..	..	..	66·7	68·0	61·8	..	..	..	22·4	26·3	24·0	13·50	13·18	13·46	7·18	8·00	7·70
														b–a, c–a			*a–b, c–b*			*a–b*	
1934–35	3·11	2·75	2·66	92·5	88·8	74·7	71·1	66·9	59·4	51·0	55·5	49·6	26·0	23·0	21·4	13·44	13·54	13·56	8·46	7·32	6·86
		a–c, a b			*a–c, b–c*			*a–b, a–c*						*a–b, a–c*						*a–b, b–c*	

* Results given as means per vine.

* Number of replications = 57 in Experiments 1 and 2; 27 in Experiments 3 and 4.

treated and control vines, nor was there any difference in the yield of fresh fruit. The sugar content of the fruit from the tipped vines was again definitely less than that of the controls, and, though the dry yield of the former was not significantly less, it showed a definite tendency to fall below that of the controls. A series of Baumé tests of the fruit on these vines showed that the difference in sugar content at harvest was associated with a lag in the maturation of the fruit of the tipped vines. The following figures illustrate this point—

Date.	Degrees Baumé.		Difference.
	Controls.	Tipped.	
3rd February, 1933	10·4	10·1	Not significant
10th February, 1933	11·6	11·3	Significant
17th February, 1933	12·7	12·2	Significant

Shoot growth, as shown by the weight of prunings, was also reduced. During the fourth season, results similar to those of the third season were obtained.

The depressing effect of tipping upon the vegetative vigour of these vines is further illustrated by the following observations. Firstly, during the third season an average 43.5 metres of sound wood was produced on each control vine while only 29.6 metres was produced per tipped vine, the difference being significant. Secondly, it was noted that the effect of tipping during the first season was to induce the formation of laterals. As the experiment progressed, the production of laterals by the tipped vines decreased, and by the fourth season actually more laterals were developed on the controls than on the treated vines. In the latter, lateral development appeared to be limited to a single long terminal on each shoot. Thirdly, the percentage of double shoots (i.e., those arising at one node) was significantly greater in the tipped vines than in the controls during the second season of treatment, but during the third season such shoots were significantly less numerous on the treated vines. Finally, it was found that the effect of tipping on the weight of prunings persisted for at least one season after the treatment terminated. In 1934-35, half of the tipped vines, selected at random, were left untreated, but the usual records were made during 1935-36. These data are shown in Table 3. Unfortunately, the reduction in the number of units reduced the precision of the experiments, and significant results were obtained only in the case of the weight of prunings. The yield results suggest that a persistence of the low sugar content of the fruit also occurred.

TABLE 3.

Treatment.	Yield Fresh Fruit, 1936.	Yield Dried Fruit, 1936.	Number of Bunches.	Degrees Baumé.	Weight of Prunings July, 1935.
	lb.	lb.			lb.
Control	34·3	11·40	55	13·38	6·52
Tipped	34·8	10·70	54	13·18	4·76
Untipped	36·1	12·03	53	13·04	4·74

Experiment 2.—In Experiment 2, similar vines on an adjacent plot were used, and a comparable, though more severe, treatment applied. Instead of removing the growing tip only, as in Experiment 1, about nine inches of the shoot was cut off and all shoots were treated. This treatment might thus be termed drastic topping.

The effects of drastic topping were comparable with, but more marked than, those of tipping. The yield of the topped vines was slightly greater, though not significantly so, than that of the controls during the first season. Fruit-bud formation was increased, and the consequent increase in the yield of fresh fruit during the second season more than compensated for its lower sugar content, with the result that the yield of dried fruit from the treated vines was also significantly greater than that from the controls. During the third season, however, the yield of fresh fruit from the control vines was greater than that of the topped, the sugar content was greater, and the yield of dried fruit was also substantially higher. By the third season, the depressing effect of the treatment on the vegetative vigour of the vines was significantly manifest in both the number of buds and shoots produced per vine and the weights of prunings obtained at the end of the season.

The treatment was discontinued after the third season, but records were kept of the performance of the vines during the two following seasons. These data are included in Table 2. During the first season (1934-35) after treatment had ceased, the "topped" vines again produced a significantly lower yield of fresh fruit of lower sugar content than the controls and again the yield of dried fruit was depressed. Decreased vegetative vigour, as shown by the weight of prunings, also persisted. During the second season after the cessation of topping, no depression of yield was apparent, though reduced vegetative vigour was still a feature of the "topped" vines. It might be pointed out here, however, that the season 1935-36 was a year of general low fertility. The mean yield of the controls was so low that it seems hardly likely that the after effects of any treatment would have lowered it appreciably.

During the winter of 1933, six typical canes were selected from each treatment in this experiment and from the tipped vines in Experiment 1. These were subjected to chemical analysis to determine starch content and the mean results were: Control 6.80 per cent., tipped 4.96 per cent., and topped 4.28 per cent. The difference between the control and topped vines was significant. The loss in vegetative vigour accompanying tipping and topping is apparently associated with a reduction in the amount of carbohydrate reserves.

Experiment 3.—The vines used in this experiment were extremely vigorous and high yielding.

Three treatments were applied, viz., (*a*) control untipped, the growing shoots being wrapped around the trellis wires, (*b*) shoots near the crown of the vine tipped, and (*c*) all shoots tipped. In treatment (*c*) the terminal shoots on the canes were tipped in late October and, in November, when the shoots from the crown of the vine had reached a satisfactory length, all shoots were tipped. A third tipping was given to all shoots in early January.

Both treatment (*b*) (shoots at crown of vine tipped) and treatment (*c*) (all shoots tipped) resulted in an increase in yield of fresh fruit

during the first season. This increase was significant only in the case of treatment (*b*), but a significant increase in the yield of dried fruit from treatment (*c*) was obtained. A considerable increase in fertility also accompanied treatment (*c*). During the second season the effect of tipping on the yield of fresh fruit was comparable with that indicated by Experiments 1 and 2. Unfortunately, owing to rain, no Baumé determinations could be made this season, and thus it was not possible to calculate the dry yields. During the third season, hailstorms partially destroyed the crop and rendered yield figures valueless. During the fourth season, treatment (*c*) resulted in a significant loss in yield as compared with treatment (*b*) and the controls. The depressing effect of both treatments on vegetative vigour was again manifest in reduced weight of prunings during the third and fourth seasons of treatment.

In this experiment it was also noted that tipping all the shoots (treatment (*c*)) resulted in the production of stockier canes with shorter internodes than normal. During June, 1933, a large number of canes were measured. The results are summarized below—

Treatment.	Mean Diameter of Canes at First Internode.	Mean Internode Length of Canes.
	mm.	cms.
(*a*)	14·90	7·06
(*b*)	14·90	6·76
(*c*)	16·00	6·43

Difference—(*a*)–(*c*) significant. (*a*)–(*c*) significant.
(*c*)–(*b*) significant.

Experiment 4.—The same treatments as in the preceding experiment were applied to a block of vines of low vegetative vigour, but only two tippings were required and therefore no treatment was applied in January. Neither treatment (*b*) or (*c*) had any effect upon the yield of the first season. Both treatments significantly increased the yield of fresh fruit during the second season, but the reduction in sugar content was most pronounced. This had the effect, in treatment (*c*), of making the yield of dried fruit significantly lower than that of the controls. During the third season both treatments reduced the yield of fresh and dried fruit. A reduction in vegetative vigour comparable with that observed in the previous experiments accompanied the treatments during the third season. The effect of tipping all shoots was more marked on yield and vegetative vigour than tipping the shoots near the crown of the vine only.

Experiments 5 *and* 6.—Two experiments were conducted in order to determine the relation between the time of tipping and its effect. In the first of these experiments (Experiment 5), a block of very vigorous vines was used and tipping carried out once at flowering time (November 8th). In the second experiment three treatments, viz. (*a*) control, (*b*) drastically topped 1st October, and (*c*) drastically topped 8th November, were applied. In both experiments, 34 replications were used, and the data obtained during the season following treatment are summarized in Table 4.

TABLE 4.— EFFECT OF TIME OF TIPPING.

Treatment.	Mean Number of Bunches.	Mean Yield of Fresh Fruit	Specific Gravity of Juice, Degrees Baumé.	Mean Yield of Dried Fruit.
		Experiment 5.		
		lb.		lb.
Control	68.5	79·6	11·20	18·20
			(*a*)–(*b*)*	
Tipped	68·0	83·0	10·66	17·70
		Experiment 6.		
(*a*)	..	36·5	..	9·35
		(*a*)–(*c*)*, (*b*)–(*c*)*		(*a*)–(*c*)*, (*b*)–(*c*)*
(*b*)	..	36·9	..	9·39
(*c*)	..	28·0	..	6·74

* Where the difference between means is significant it is shown thus :—e.g. (*a*)–(*b*).

A single tipping at flowering time resulted in a depression of the sugar content of the fruit at the following harvest, although the net effect on both the yield of fresh and dried fruit was not significant. Drastic topping at about the same time resulted in a very significant reduction in the yield of both fresh and dried fruit at the next harvest. Drastic topping some five weeks earlier (1st October) did not appreciably affect yield. These results, taken in conjunction with the information obtained from Experiments 1-4, seem to indicate that treatment early in the season is not so severe in its effect.

(*b*) *Conclusions.*

The general conclusions to be drawn from these trials would seem to be as follows:—

(i.) The effect of tipping or topping depends upon the severity of the treatment, the time of treatment, and the vigour of the vines.

(ii.) During the first season, yield is usually slightly increased in vigorous vines, though very severe treatment may (depending on the time of application) actually lower it. Lateral development and fruit bud formation are stimulated in all vines.

(iii.) During the second season, a marked increase in the yield of fresh fruit occurs, the advantage of which is offset to some extent by a drop in sugar content.

(iv.) During the third and subsequent seasons of treatment, the vegetative vigour of the vine decreases, starch accumulation diminishes, and there is generally a decline—probably progressive—in the yields of both fresh and dried fruit. The more severe the treatment, the more rapidly do these effects become manifest.

(v.) Tipping or topping should never be practised as a means of increasing yields. Any form of tipping is detrimental to vines of low vigour, and any form except the mild tipping of shoots near the crown of the vine has proved to be harmful to vigorous vines. It is also probable that even the mildest form of tipping ultimately tends to a decline in vegetative vigour.

The excessive growth of very vigorous vines sometimes interferes with cultural operations, and considerable labour may be saved by tipping the growing shoots instead of wrapping them to the trellis wires. If practised under such conditions, topping should be reduced to a minimum. An advantage has also been claimed for tipping in that the additional lateral growth produced by the treatment helps to shade the crop and prevent sunburn. Actually, the protection of fruit from sun scald is of practical importance only in vines of low vigour with very sparse foliage. The harmful effect of tipping such vines far outweighs any advantages obtained in shielding the fruit from the sun.

4. Cincturing Experiments.

Two major experiments were carried out; the first was designed to determine the effect of a single cut cane cincture at flowering time (early November) on setting and yield; the second was planned to obtain information regarding the effect of a wider double cut girdle made later in the season (December-January) on the development of the current crop and the buds for the ensuing year. In the latter experiment a girdle approximately 3-16ths of an inch wide was made during late December in the canes just beyond the first few sterile shoots. This girdle had almost healed over some 28 days later, and in the first two seasons of treatment was then renewed. During the third season, only one girdling in late January was applied. In both experiments vigorous vines were used, and the trials extended over three seasons. The data are summarized in Table 5.

The reaction of the vines was much the same for both the light-early and severe-late types of cincture, and may be stated briefly as follows:—

(*a*) Cincturing the cane tends to increase the yield of fresh fruit during the first season of treatment but depresses its sugar content. The lower specific gravity of the juice does not completely offset the increase in weight of fresh fruit, however, and the dry yield is also greater than that of the controls.

(*b*) During the second season of treatment, vegetative vigour is adversely affected; the yield of fresh fruit and its sugar content, as well as the yield of dried fruit, are depressed.

(*c*) During the third season, the yields of fresh and dried fruit are again lower than those of the controls.

(*d*) Cane cincturing has no appreciable effect on fruit-bed formation.

TABLE 5.—THE EFFECTS OF CINCTURING THE SULTANA.

a = controls. c = treated.

Treatment.	1933–34. (a)	1933–34. (c)	1934–35. (a)	1934–35. (c)	1935–36. (a)	1935–36. (c)	June, 1936. (a)	June, 1936. (c)
Experiment 1.*								
Weight of prunings in lb.† ..	..	..	8·78	‡7·97	7·50	7·20	..	..
Number of bunches ..	48·6	42·9	80·3	77·9	..	..	..	..
Yield of fresh fruit in lb. ..	57·9	66·6	58·2	57·3	50·9	‡31·6	..	..
Degrees baumé of juice ..	11·40	‡10·80	..	..	..	..	..	..
Yield of dried fruit in lb. ..	13·42	14·38	16·43	15·78	11·12	‡7·83	..	..
Experiment 2.*								
Weight of prunings in lb. ..	..	..	6·00	5·55	4·96	5·32	8·24	‡6·54
Number of shoots ..	..	..	87·3	76·9	86·8	76·8	..	..
Number of bunches ..	41·6	40·0	56·3	51·5	26·8	25·0	..	..
Yield of fresh fruit in lb. ..	23·9	30·7	53·1	45·4	23·2	21·2	..	..
Degrees baumé of juice ..	12·80	‡12·41	11·90	‡11·50	..	..	..	..
Yield of dried fruit in lb. ..	6·35	‡9·85	14·54	‡11·23	7·32	5·56	..	..

* In Expt. 1, 28 replications, and in Expt. 2, thirteen replications were used.
† Results are given as means per vine.
‡ Indicates that the difference between the means is significant.

It is to be noted that significant results were not obtained in support of all the above conclusions in both experiments. For instance, in the third season significantly different yields were obtained only in the single cut trials. Nevertheless, it is extremely probable that the effects of both treatments were comparable and the level of significance was not obtained in the second experiment only because of the small number of replications employed.

In view of the practical difficulties of obtaining statistical records, actual berry counts were not made to determine whether cincturing at flowering time had any effect upon setting. However, since girdling in the second experiment took place too late in the year to affect setting and yet caused an increase in yield during the first season comparable with that resulting from early cincturing, it may be inferred that the response to the early cincturing was also independent of setting. Indeed, as neither setting nor fruit-bud formation seems to have been affected by girdling, it becomes interesting to consider the manner in which the treatments did effect an increase in yield during the first season. The weight of fresh fruit produced by the cinctured vines was considerably increased, although the specific gravity of the juice was lower than that of the controls. On the other hand, the total amount of sugar in the fruit was increased, since yields of dried fruit

from the cinctured vines were also higher. These seemingly paradoxical conditions are explained by the observation that the berries of the treated vines grew abnormally large. In California this response is recognized and late cincturing is often practised on the Thompson's Seedless (Sultana) when grown for fresh fruit. Denser bunches with large turgid berries desirable for table purposes are produced. Such a bunch type is, however, definitely undesirable for dried fruit production, owing to the greater tendency of turgid berries to split after rain during the ripening period and because of their liability to mould attack.

Analyses showed that neither the percentage ash nor nitrogen content of the dried fruit from the treated vines differed to any extent from that of the controls. Four representative samples of dried fruit were selected during March, 1934, and the results of analyses were as follows: Total nitrogen in control 0.40 per cent., and in cinctured 0.38 per cent.; total ash in control 1.96 per cent., and in cinctured 2.00 per cent. of the dry weight. The yield increment obtained during the first season of treatment consists essentially of reducing sugars, which normally constitute 80 to 85 per cent. of the dried fruit. On the other hand, the carbohydrate reserves stored in the canes were not increased by girdling. During June of the same season (1934), a composite sample from canes was selected from each of seven vines in each treatment and starch determinations were made. The results were as follows:—Control canes 5.06 per cent. and cinctured 5.22 per cent. of the dry weight, and the difference was quite insignificant.

The failure of ringing to cause an increase in carbohydrate accumulation within the wood above the girdle is contrary to the usual effect of this operation in horticultural plants. The girdle generally results in a check to the downward migration of sugars, though its effect on the upward movement of soluble nitrogen and minerals is still somewhat obscure*. Our experience would indicate that late season ringing of the sultana results in an increased growth of the berries and a local accumulation of sugar within the fruit but no starch accumulation in the canes. The failure to increase starch accumulation above the girdle may account for the fact that increased fruit-bud formation, which generally accompanies the operation in other plants, is not a feature of the reaction of the sultana.

The reduction in carbohydrate accumulation in the fruit and the decline in vegetative vigour associated with cincturing during the second and third season of treatment appears to be related to a decrease in the carbohydrate reserve in the old wood (i.e., the trunk) below the girdle, During 1936, samples were obtained by boring the trunks of six vines from each treatment in Experiment No. 1 (cincturing at setting time). The means of the starch determinations on these samples were as follows:—Control 7.08 per cent. and cinctured 6.18 per cent. The difference, although considerable, was below the level of significance, but it might reasonably be supposed that ringing actually did result in a depletion of starch reserves in the trunk. The decrease in yield appears to be rather greater than can be accounted for by the effect of the operation on vegetative vigour and fertility, and therefore it would

* A comprehensive summary of an investigation dealing with the physiological effects of girdling is given by D. A. Akenhead in "Ringing Fruit Trees—The Present Position," Mimeographed, Imp. Bureau Fruit Prod. 1930.

seem that, although doubt has been expressed as to whether there is normally any upward movement of carbohydrates from trunk to leaves*, the reserve carbohydrate content of the trunk and older wood plays a role of considerable importance in maintaining growth and fruit production.

5. Disbudding Experiments.

Two disbudding experiments were carried out: in the first all barren shoots were removed on the 1st of October, while in the second the operation was not performed until late November, when the shoots were approximately 80 to 100 cms. long. The results, expressed as mean values per vine, are set out in Table 6. Forty-eight replications were used in Experiment 1, and 29 in Experiment 2.

TABLE 6.—THE EFFECT OF DISBUDDING.

a = control. *d* = disbudded.

Expt. 1.	1932–33.		1933–34.	
	a	*d*	*a*	*d*
Weight of prunings ..	..	..	8·57 lb.	8·60 lb.
Total length of shoots in June	..	..	56·1 metres	55.9 metres
No. of bunches ..	..	..	44·0	42·0
Field of fresh fruit ..	54·9 lb.	59·5 lb.	49·3 lb.	49·0 lb.
Degrees Baumé of juice	9·35*	9·38*	11·30	11·56

Expt. 2.	1934–35.		1935–36.	
	a	*d*	*a*	*d*
Total number of shoots ..	..	..	82·4	75·6†‡
Per cent. of shoots removed	..	23	..	27
Weight of fresh fruit ..	49·2 lb.	45·5 lb.	28·8 lb.	24·9 lb.‡
Weight of dried fruit ..	14·64 lb.	14·45 lb.	8·64 lb.	6·35 lb.‡

* Taken ten days prior to harvest.
† Prior to disbudding.
‡ The difference between means is significant.

These data indicate that early disbudding (Experiment 1) had little influence on either yield or vegetative vigour. The total amount of shoot growth made during the second season of treatment was not affected, and it is presumed that the remaining shoots grew to a greater length.

On the other hand, when disbudding was carried out later in the season after a considerable length of shoot and leaf area had been

* Curtis, O. F. *American Journal Botany,* 7: 101, 1920.

developed, the effects were manifest during the following season. Not only was there a decrease in the number of shoots developed, but the yields of both fresh and dried fruit were significantly depressed.

Jacobs* has shown that elaborated nutrients may move from a shoot for several feet along the cane supporting it. A barren shoot may thus play an important part in the economy of the vine, and its nett contribution to the yield of the vine may considerably outweigh its own dry-weight equivalent. Certain correlation studies by Lyon† illustrate this point. The correlation coefficients were:—Length of central fertile shoots and yields of fruit borne thereon, $r = .45$; and total length of all shoots on cane and total yield per cane, $r = .71$. The cane, with its complement of shoots, both sterile and fruitful, may be considered a unit, and any loss in elongation growth, whether of barren or fruitful shoots, may be expected to lead to a reduced yield.

Our results indicate that disbudding early in the season is unnecessary, and if done later, distinctly undesirable.

6. Acknowledgments.

The writers are indebted to Messrs. C. H. Cameron, J. Giles, W. Lyell, and J. Sharpe for most valuable assistance during the course of these experiments.

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* *Proc. Amer. Soc. Hort. Sci.*, 32: 387, 1934.
† *Aust. Dried Fruit News*, Nov. 1933 Supplement.

PLATE 1.

The Influence of Host Plant Species in Relation to the Effectiveness of the Rhizobium of Clovers. (See page 12.)

(*Photograph by A. D. Cocks*)

FIG. 1.—Relative effectiveness of strains of *Rhizobium trifolii* upon subterranean clover.

4. Inoculated with strain from white clover.
5. Inoculated with partially effective strain.
6. Inoculated with highly effective strain from subterranean clover.

(*Photograph by A. D. Cocks*)

FIG. 2.—Relative effectiveness of strains of *Rhizobium trifolii* upon white clover.

3. Inoculated with strain from subterranean clover (cf. Pot 6, Plate 1).
5. Inoculated with partially effective strain.
8. Inoculated with strain from white clover (cf. Pot 4, Plate 1).

PLATE 2.

The Influence of Host Plant Species in Relation to the Effectiveness of the Rhizobium of Clovers. (See page 12.)

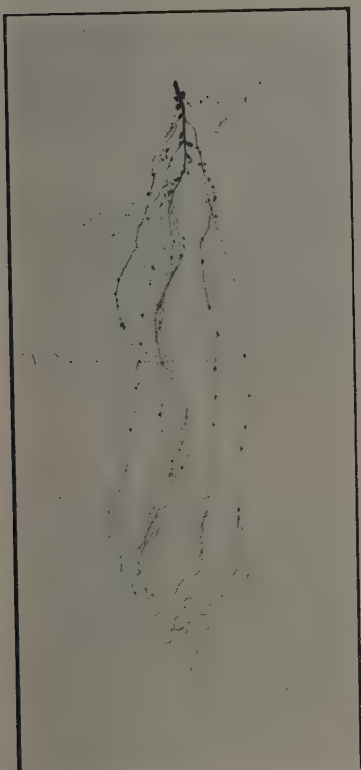
(*Photographs by A. D. Cocks*)

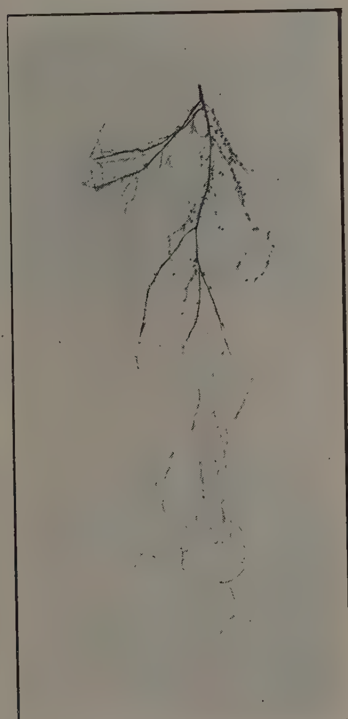
FIG. 1.—Ineffective nodulation (subterranean clover). Root system ex Pot 4, Plate 1. Inoculated with strain of *Rhizobium* isolated from white clover.

FIG. 2.—Effective nodulation (subterranean clover). Root system ex Pot 4, Plate 1. Inoculated with strain of *Rhizobium* isolated from subterranean clover.

PLATE 3.

The Influence of Host Plant Species in Relation to the Effectiveness of the Rhizobium of Clovers. (See page 12.)





(Photographs by A. D. Cocks)

Fig. 1.—Effective nodulation (white clover). Inoculated with white clover strain identical with that upon root system of Plate 3.

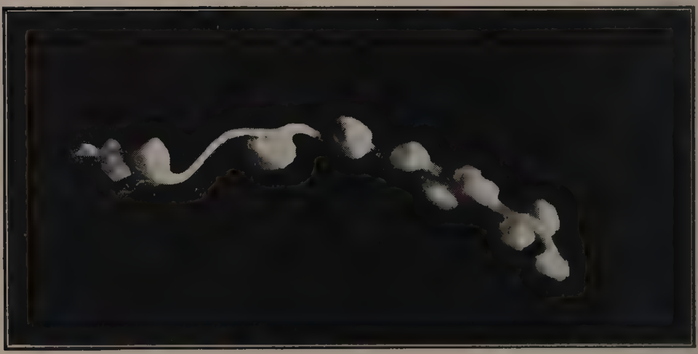
Fig. 2.—Ineffective nodulation (white clover). Inoculated with subterranean clover strain identical with that upon root system of Plate 4.

PLATE 4.

The Influence of Host Plant Species in Relation to the Effectiveness of the Rhizobium of Clovers. (See page 12.)

(*Photograph by A. D. Cocks*)

FIG. 1.—Effective nodules, ex root system Plate 4.



(*Photograph by A. D. Cocks*)

FIG. 2.—Ineffective nodules, ex root system Plate 3.

NOTES.

Influence of Improved Pastures on Fine Wool Production.

(Contributed by the Division of Animal Health and Nutrition.)

Though there is now general agreement as to the possibilities for greatly increased production of fat lambs and crossbred sheep on improved pastures, there is considerable disagreement amongst practical sheep men as to the possibility of augmented production of Merino and particularly fine wools on such pastures. It is frequently asserted that fine wool sheep run on improved pastures will show rapid deterioration in wool quality with great coarsening of the wool fibre. Previous field trials of the Council for Scientific and Industrial Research in New South Wales and Tasmania have shown that, in respect to Corriedales and crossbred sheep, the changes in wool type induced on such pastures have been very much less than might have been expected and that, although the weight of greasy and clean-scoured wool produced per head was greatly increased, there was relatively little change in the quality of the wool.

In order to determine the effects of improved pasture on fine and superfine wools, officers of the Division of Animal Health and Nutrition and of the Australian Pastoral Research Trust have recently conducted a field trial on Mr. W. T. Merriman's property, Merryville, Yass. The experimental sheep comprised two groups each of 55 hoggets which were selected on the basis of individual body weights, fleece weights, and fleece quality, so that the groups were exactly comparable. One group was run on improved pasture at the rate of 3 sheep per acre for a period of 12 months, while, in addition, the paddock accommodating these sheep was stocked with as many as 20 sheep per acre for short periods in the spring and summer. The improved pasture in this paddock was about 57 per cent. subterranean clover but included no English grasses, whereas less than 1 per cent. of subterranean clover was present in the natural pasture area. The edible yield of the pastures in the two paddocks was as follows:—

Improved pasture.—61 per cent. clover
36 per cent. grass
3 per cent. miscellaneous.

Natural pasture.—99½ per cent. grass
½ per cent. miscellaneous
traces clover.

At the shearing *prior* to the commencement of the trial, the sheep subsequently placed on natural pasture cut an average of 6 lb. 7 oz. greasy wool per head, and the sheep subsequently placed on improved pasture 6 lb. 6 oz. per head. During the course of the trial, little difference in body weight between the two groups was noticed during the spring and summer months, but, from March onwards, the improved pasture group steadily drew away from those on natural pasture and at the conclusion of the trial the former averaged 100.5 lb. live weight and the latter 79.26 lb. Both groups were shorn on 28th October, with the following results:—

The improved pasture group cut 11.1 lb. greasy wool, with an estimated clean scoured yield of 62.75 per cent.

The natural pasture group cut 8.92 lb. with an estimated clean scoured yield of 61.4 per cent.

The fleeces of the natural pasture group showed the following percentages of the various qualities:—Under 70's—1.8 per cent.; 70's—20 per cent.; 74's—32.7 per cent.; 80's—45.5 per cent. The improved pasture group showed under 70's—11.5 per cent.; 70's—36.5 per cent.; 74's—40.4 per cent.; 80's—11.5 per cent. There was no difference between the wool of the two groups in respect to colour and handle, but the average staple length of the improved pasture group was 3.28 inches compared with 2.98 inches in the natural pasture group.

Observations made on the degree of parasitism in the two groups showed no appreciable difference during the summer and autumn months, and both groups were drenched on three occasions in the summer and autumn. Subsequently, during the winter the improved pasture group almost completely threw off all worm infestation, whereas the natural pasture group continued to show some degree of infestation.

As a result of the trial, it is seen that improved pastures capable of maintaining over 3 sheep to the acre throughout the year and leading to greatly increased wool production per head, led to relatively slight strengthening of the wool, the transition from natural pasture to improved pasture wool types being merely that from a 74/80's wool to 70/74's. It is interesting to note that the trial sheep in the improved pasture group cut 33.3 lb. wool per acre compared with 8.92 lb. per acre on natural pastures, while it must be remembered that, in addition to the trial sheep, considerable numbers of other sheep were maintained on the improved pasture for short periods.

It cannot be assumed from this experiment that all fine wool sheep would show as little change in wool type as did the trial sheep when subjected to the better nutritional conditions made possible by improved pasture, it being necessary to distinguish between "starvation" fine wools and those determined by hereditary factors. There are, however, good grounds for believing that sheep which are growing fine wool primarily as a result of their breeding will continue to produce such wools even when run on improved pastures.

The trial will be continued with certain modifications for another year.

Contributions from Industry to the Division of Forest Products.

During recent months, several industrial organizations have shown their appreciation of the work of the Division of Forest Products in a tangible way by making very appreciable contributions to the cost of the Division's operations. These contributions include the following:—

The Queensland Forestry Sub-Department has given a further contribution of £250, making £500 in all, in order to facilitate the Division's work on problems of interest to Queensland and in particular the production of veneers.

The Australian Oxygen and Industrial Gases Pty. Ltd. has made another donation of the sum of £50 on account of the Division's

investigations into the effect of the coal gas flame for the charring process and the preservation of poles. Altogether this company's contributions to the Division now amount to £150.

The New South Wales Forestry Commission has promised the sum of £100 towards the cost of the timber necessary for the completion of the roadway (over a drain) at the Division's new laboratory at South Melbourne.

General Motors-Holdens Ltd. has made another donation, this time of 100 guineas, in recognition of "the excellent work that is being performed by your Council, and for assistance rendered from time to time to this Company".

Messrs. Gibbs, Bright & Co. have donated £30 in appreciation of the Division's assistance in connexion with certain difficulties involving the utilization of *Pinus radiata*.

Henry Jones & Co. Ltd. have given £50 as a donation towards the cost of the Division's new laboratory as a mark of appreciation of assistance rendered to it.

The Queensland Plywood Board has given a second donation of £100 towards the cost of investigations into glueing and preservative problems.

Tests of Mitchell Grass Hay.

The practicability of conserving, in the form of hay, some of the natural fodder grasses of the inland pastoral country of Australia has long been a matter of controversy. The limited extent to which this form of drought provision is practised can be attributed to several causes. Probably the most important is the realization that it is quite beyond the power of the average pastoralist to cut and stack sufficient quantities of hay to feed thousands of sheep during even a short drought period. Then there is the widespread belief that cutting for hay must interfere seriously with the regeneration of the grass. Then again there is the recognized fact that Mitchell grass (which, as the dominant fodder plant over considerable areas of inland pastoral country, especially in Queensland, is the species that must receive first consideration) grows with great rapidity and loses its nutritive value so quickly that the period during which it is worth cutting for hay is very short.

From some of the few graziers who adopt the practice of hay conservation on their properties, it has been ascertained that if the obvious precaution is taken of allowing the grass to seed at least once between the times at which it is mown, cutting does not interfere with the regeneration of Mitchell grass. Moreover, although it is only possible to conserve a sufficient quantity of hay to feed a proportion of the flock (naturally the top breeding lines and stud animals will be selected), the practice pays because the hay is cheaper than fodder bought in the open market.

Following suggestions made to the Council by a member of a pastoral company with properties in the Queensland Mitchell grass belt, it has been decided to investigate the nutritional value of Mitchell grass hay. It is hoped that the results of these experiments, which will be undertaken by the Council's Animal Nutrition Laboratory at

Adelaide, will allow the economic value of the hay to be assessed, and thus provide data which will afford practical guidance to graziers who may be contemplating hay conservation. The capacity of the grass to support the energy requirements and to supply the materials for wool growth will be investigated at two stages of maturity.

Mr. H. Miller, "Coreena Stud," Barcaldine, Queensland, has kindly undertaken to provide the Council with the hay required for the tests, which will be carried out during the present year.

Investigations Concerning Fertility in Sheep.

For some time past, Mr. R. B. Kelley of the Council's Division of Animal Health and Nutrition has been inquiring into certain genetical problems of the Australian Merino sheep, including that of fertility. In connexion with that work he has given much attention to the study of stud records.

Dr. R. M. C. Gunn of the University of Sydney has been carrying out work concerning the reproductive organs of rams and having a considerable bearing on the fertility of such animals. It will be remembered that a year or so back, with the consent of Dr. Gunn, the results of some of this work were published by the Council as its Bulletin 94. Since that time Dr. Gunn has continued his investigations, more particularly from the point of view of determining the fertility of rams maintained under varying climatic conditions. The Council has been able to assist him to some extent in that connexion in the way of providing travelling expenses. Incidentally, as a result of visits he has made to various sheep-raising districts of Australia, Dr. Gunn finds that the fertility of rams, as measured by semen characteristics, varies considerably throughout the year, decreasing in periods of hot weather. He now proposes to extend his work to actual mating trials. It has been arranged that this work will be carried out with the co-operation of Mr. Kelley.

The eventual aim of the investigation is to enable correct advice to be given to the breeder as to the ideal time of mating sheep to obtain maximum fertility. It will be left to the grazier to determine for himself whether it is more economic to aim at maximum fertility (that is, birth of lambs) or to accept a reduced fertility in order to avoid later mortality or losses by reason of local conditions.

The Detection of Wounding in Citrus Fruits—Preliminary Note.

(*Contributed by L. J. Lynch, B.Agr.Sc.*)

The importance of wounding as a factor in mould (*Penicillium* spp.) wastage of citrus fruits is generally accepted, and a number of methods designed to render abrasions detectable have in consequence been evolved. These consist in immersing the fruit either in dyes which colour the wound or in a reagent in leuco form with subsequent exposure to a reagent capable of generating colour in the leuco compound. Such methods are reasonably successful in practice but demand a tedious and exacting examination.

Preliminary observations indicate that wounds in fruits immersed in certain solutions exhibit a marked fluorescence when exposed to ultra-violet light. Since a number of fungal lesions of the rind exhibit a typical blue fluorescence without prior treatment, materials such as quinine, which give blue fluorescent colours, must be avoided. Of those solutions so far examined, celliton yellow and acriflavine, both of which show a brilliant yellow-green colour, and auramine, have been found satisfactory.

The ultra-violet method of detection is rapid and permits the simultaneous examination of a tray containing 50 fruits.

Fisheries Investigations.

Late in the year 1935 the Government decided to place its fisheries investigations under the control of the Council. Prior to that, work of this nature had been the function of the Development Branch of the Prime Minister's Department which was largely instrumtneal in obtaining information on which the Government decided to devote funds of the order of £16,000 p.a. over a period of five years in order that the work might be put in hand.

Considerable progress has now been made with plans for the work. Briefly, the programme of research will comprise work under the following main headings:—

(i) The exploration of fishing grounds by a specially designed vessel.

(ii) Experiments in canning and the determination of the chemical composition of fish thought to be suitable for the manufacture of fish by-products.

(iii) Tests of methods of curing and preserving fish, especially the more common varieties.

(iv) Marine biological investigations, including research into the life histories, distribution, &c., of economically important fishes.

In the early stages of the Council's part in this work, Professor Dakin of the Biology Department of the University of Sydney afforded much assistance. Incidentally, too, by the use of University facilities, he has already initiated a small programme of marine biological research.

Dr. H. Thompson, who immediately prior to his acceptance of the Council's appointment was Director of the Fisheries Research Laboratory at St. John's, Newfoundland, has recently been appointed to direct the fisheries investigations under discussion. Prior to his work in Newfoundland he was for some years attached to the Scottish Board of Fisheries. On his way out to Australia Dr. Thompson visited North America where he looked into various matters in the United States and Canada.

(*a*) *Exploration Work and Experimental Vessel.*—For the proposed exploration of fishing grounds, a special investigational vessel is now under construction by the Melbourne Harbour Trust Commissioners at a cost of nearly £20,000. It will be about 82 feet long and

19 feet in the beam, and the hull will be of steel. The boat will have Diesel engines and will be provided with the necessary apparatus to handle especially purse-seine and Danish seine types of net. From this point of view its features will be unique. Construction is expected to be complete in about August, 1937.

An appointment of a Master has now been made and the appointee, Captain A. Flett, late Master of the Australian seiner "Nanagai", left Australia early in December, 1936, to spend a few months in America making himself conversant with pelagic fisheries and technique of the Pacific coast where types of fish similar to those found in Australia are exploited.

With Australia's vast area of coastal waters the task confronting the investigational vessel is tremendous. With a view to ascertaining to what extent the work of the vessel might be assisted by aerial observations, an interesting test was recently carried out by the Fisheries Officer of the Council, Mr. S. Fowler, in co-operation with the Royal Australian Air Force. It consisted of an aerial patrol of the water of South-eastern Australia extending from Sydney in the north to Port Davey (Tas.) in the south. The observations were hampered by much bad weather and poor visibility but were successful in that it was possible to establish the areas of greatest concentration of pelagic fish life and of its related bird life. During the flights photographic work was carried out with the co-operation of the Cinema Branch of the Department of Commerce. There seems reason to believe that aerial observations will be a very helpful way of facilitating the more detailed work of the experimental vessel and will also be of distinct value in connexion with the navigation and harbouring of fishing craft and the development of the industry.

(*b*) *Analyses of Fish.*—Arrangements have recently been completed for some fish analytical work to be carried out in the Chemistry Department of the University of Melbourne. The object is to analyse different Australian fishes for their oil content, protein content, &c., such information being of value, *inter alia,* in connexion with their utilization as by-products such as fish-meal and the like. The work will be under the immediate direction of Associate-Professor W. Davies who will be provided by the Council with the services of an assistant.

(*c*) *Curing of Fish.*—The Council has recently been in touch with the Torry Fisheries Research Station, Aberdeen, in regard to work on the curing of fish. A few samples of typical Australian sawdusts have recently been sent to Aberdeen in order that some tests as to the fish-curing properties of their smokes might be carried out. It is also hoped to appoint an experienced fish curer in order to carry out more detailed work in Australia.

(*d*) *Preservation of Fish.*—When the proposed Sydney laboratories of the Section of Food Preservation and Transport have been completed, it is hoped to carry out some work on the preservation of Australian fishes by cold storage including quick freezing. Plans for this work, however, are not far advanced at the moment pending the completion of the Section's laboratories.

Chemical Work on Insecticides.

For some time past, the Council has been considering the possibilities of appointing a chemist to carry out investigations concerning insecticides and fungicides, and particularly the possibilities of using new and more potent chemical compounds for such purposes. Work of this nature constitutes a wide field of activity, and it is known that certain large chemical manufacturing firms outside Australia are devoting their attention to it. Certain aspects of the work, however, are appropriate for Australian action.

For some time past, lack of finance has been one of the chief difficulties preventing the council from doing anything. Last year, however, the Codling Moth Committee (which is representative of the various State Departments of Agriculture and of the Council) recommended that the Council should arrange for chemical studies to be carried out on various insecticides used against codling moth and particularly concerning the use of derris in sprays and the determination of standards to which spraying oils should conform.

Finance being available in consequence of the Government's decision to make £20,000 available to the apple and pear industry (see this *Journal,* 9: 137, 1936), an appointment of a chemist (Dr. J. G. Fitzgerald) has recently been made for the purpose the Codling Moth Committee has in mind. Professor J. C. Earl of the Department of Organic Chemistry of the University of Sydney, has undertaken to provide laboratory accommodation and other facilities for this investigator, and also to exercise a general supervision over the work. The work involved is now in progress.

Dairy Research—Appointment of Dr. W. J. Wiley.

With the development of the agricultural and pastoral research activities of the Council for Scientific and Industrial Research in Australia and of the Department of Scientific and Industrial Research in New Zealand, it has become clear that close co-operation in certain lines of work would be a mutual advantage. One such line is dairy research; others are mastitis in cattle, sterility, and forest products.

This whole question of co-operation was to be discussed with the New Zealand authorities by the Minister-in-Charge of the Council (Senator the Hon. A. J. McLachlan) during his visit to New Zealand on the occasion of the meeting of the Australian and New Zealand Association for the Advancement of Science. Prior to that, it was discussed by Sir George Julius during a private visit to New Zealand and also by Dr. E. Marsden (Secretary of the Department) during a recent visit to Australia.

Some time ago, the Department conveyed to the Council an invitation to arrange for an Australian officer to be located at the Dairy Research Institute, Massey College, New Zealand, to work there on some dairying problem of special interest to Australia, or to work as part of the Institute's general team. In either case, the officer would be working under the supervision of the Director of the Institute, Professor Riddet. The Department, in its turn, has in mind possibilities of its appointing officers to work in Australia on mastitis in cattle or on forest products.

The Council has now received authority to accept this invitation, and Dr. W. J. Wiley has been appointed for the purpose. He will leave Australia for New Zealand at the end of January, 1937, for a period with the Dairy Research Institute as yet undetermined.

Some years back, Dr. Wiley was an officer of the Council and played a large part in the development of the casein-formaldehyde coating of butter boxes to prevent butter taint. Prior to that, he spent two years obtaining experience in dairy research at the Dairy Research Institute, Reading, England, as a trainee financed from the Science and Industry Endowment Fund. Since the end of 1932 he has been an officer of the Government Analyst, Brisbane.

Fourth International Grassland Congress, Great Britain, 1937.

The Fourth International Grassland Congress is to be held in Great Britain in 1937, under the Presidency of Professor R. G. Stapledon, C.B.E., M.A., Director of the Welsh Plant Breeding Station, and of the Imperial Bureau of Plant Genetics: Herbage Plants, Aberystwyth. The congress is the fourth of a series which has been arranged for the meeting of specialists in grassland research and management from a number of countries.

According to present plans, the paper-reading sessions of the fourth congress will be held at Aberystwyth, on July 15 to 18, 1937 (enrolment on July 14). Intending participants will be invited to join in a tour of centres of grassland interest both before and after these sessions. The tour will be made partly by motor coach and partly by rail.

The paper-reading sessions have been tentatively arranged to cover the following subjects; this classification will be adjusted to suit later requirements.

(1) Ecology (including surveys), pasture management (including erosion control).
(2) Seeds mixtures (including lucerne for grazing); legumes for use in poor pastures.
(3) Plant breeding, genetics, and seed production.
(4) Manures and fertilizers.
(5) Nutritive value of pastures: fodder conservation.
(6) Grassland economics.

It is important that the Joint Secretaries (whose address is Agricultural Buildings, Aberystwyth, Great Britain) should receive at least a tentative notification of intention to attend the congress from those who wish to do so. Such tentative notification will be welcome as soon as possible.

Recent Publications of the Council.

Since the last issue of this *Journal*, the following publications of the Council have been issued:—

Bulletin No. 102—"Studies of Selected Pasture Grasses. The Measurement of the Xerophytism of any Species," by T. B. Paltridge, B.Sc., and H. K. C. Mair, B.Sc.

For some years past, the Council's Division of Plant Industry has been sedulously investigating the characteristics of grasses and other pasture plants in the various grazing areas of the world in the hope of discovering varieties that would be valuable in Australia, particularly in the drier portions of the Continent. Up to date, some 800 different grasses have been brought into Australia by the Division, and they are now being tested as to their characteristics. Work of this nature is considerably helped by a quick method of ascertaining the capacity of any introduced grass to establish itself in dry regions. Trials over a period of years would eventually settle this question, but such methods are time-consuming. The Division has accordingly devoted itself to developing a rapid method of assessing plants from the point of view of their drought resistance; the results are published in Bulletin 102. The method developed consists of growing plants of the different grasses under approximately similar glasshouse conditions, then removing the entire plant from all contact with the soil, and allowing it to dry out in the laboratory environment while being weighed at regular intervals of about 5 minutes. The weights at various times are then plotted, and from the shape of the resultant curve it has been found that a fairly close idea of the capacity of the plant to resist dry conditions can be obtained.

Bulletin No 103—"*Wojnowicia graminis* (McAlp.) Sacc. and D. Sacc. in relation to Foot Rot of Wheat in Australia," by W. V. Ludbrook, B.Agr.Sc., Ph.D.

In Australia, wheat is subject to various varieties of foot rots which have recently been estimated to be the cause of a reduction of yield of about 4 per cent. in one year alone in New South Wales. Such a loss is not easily observable in the field, but yet it occurs in most seasons. The problem of its control is one of considerable complexity, because several organisms may be involved as causes, either alone or in association, and each may be affected by soil, climatic, and other factors. It has become evident that to make systematic headway in the control of the disease, it is necessary to advance fundamental knowledge of the life of the microscopic organisms inhabiting the soil, including a determination of those which give rise to foot rot. Work of that nature is discussed in the Bulletin. It is found that *Wojnowicia graminis*, although widely distributed in Australian wheat fields and frequently found on foot-rotted plants, is not the cause of Australian foot rot.

Pamphlet No. 67—"The Shrinkage of Australian Timbers. Part I. A New Method of Determining Shrinkages and Shrinkage Figures for a Number of Australian Timbers," by W. L. Greenhill, M.E.

The shrinking and swelling which accompanies changes in the moisture content of woods are its greatest disabilities from this point of view, and the Pamphlet gives the results of some work carried out by the Division of Forest Products in order that further knowledge of shrinkage properties of Australian timbers might be obtained. The mechanism of shrinkage and the cause and effect of collapse are discussed, and it is pointed out that various established methods of determining shrinkage are open to criticism in that they neglect the effect of collapse and drying stresses. The shrinkage which would occur if collapse and drying stresses were entirely eliminated has been called "basic" shrinkage, and a method has been developed whereby "basic"

shrinkage can be determined very closely. The method depends on the use of small samples which are cut so that the dimension along the grain is less than $1\frac{1}{2}$ times the fibre length. The relation of "basic" shrinkage as so determined to that of other methods is discussed.

"C.S.I.R.—Ten Years of Progress". This publication of some 67 pages contains a popular account of the work of the Council in the first decade of its existence. In a foreword by the Minister-in-Charge of the Council (Senator the Hon. A. J. McLachlan), it is pointed out that the only comprehensive account of the work of the Council is to be found in its Annual Reports, which, however, are technical in character and of limited circulation. It has accordingly been thought that the completion of the tenth year of the Council's existence is an appropriate occasion for the issue of this review of the Council's work.

Forthcoming Publications of the Council.

At the present time, the following future publications of the Council are in the press:—

Bulletin No. ?—"Investigations on the Inheritance of the Grass Clump Character in Crosses between Varieties of *Triticum vulgare* (Vill.)", by J. R. A. McMillan, B.Agr.Sc., M.S.

Pamphlet No. ?—"A Guide to the Seasoning of Australian Timbers Part II.", by W. L. Greenhill, M.E., and A. J. Thomas, Dip.For.

H. J. Green, Govt. Printer, Melbourne

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